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**New!**

# MEADE LX90

## 8" LX90
## $1695

**Now you can buy the telescope of a lifetime at a price you probably never thought possible!**

The Meade 8" LX90, with diffraction-limited Meade® optics in an all-new Autostar™ computer-controlled telescope system, includes capabilities not available on competing 8" Schmidt-Cassegrains that cost hundreds of dollars more. And, at $1695, the 8" LX90 — *with more than twice the light-gathering power* — is priced only a few hundred dollars more than competing 5" Schmidt-Cassegrains!

**Q: What is new and different about the Meade 8" LX90 Schmidt-Cassegrain?**

**A:** The Meade 8" LX90 is the first full-capability, computer-controlled 8" Schmidt-Cassegrain ever offered in its price range.

**Q: What do you mean by *full-capability?***

**A:** We believe that the great majority of amateur astronomers want their telescope not only to be a high-resolution visual observing instrument but also to be fully qualified for the more advanced areas of astronomy, including long-exposure CCD imaging and astrophotography. As detailed below, the LX90 meets all requirements in these areas.

**Q: What features not included on competing telescopes enable the LX90 to meet these advanced requirements?**

**A:** A few of these features include: (a) a die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations; (b) *worm gears* of 4.9"-diameter on both telescope axes that permit smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging; (c) a chromed-steel variable-height tripod that provides all the rigidity required in sensitive field applications — *in fact, the same tripod as provided with Meade LX200 models.*

MEADE LX90 EMC
SCHMIDT-CASSEGRAIN
COMPUTER CONTROL
AUTOSTAR
MEADE
ENTER
MODE
GO TO

**Meade 8" LX90 Schmidt-Cassegrain Telescope — complete as shown with Autostar hand controller and variable-height field tripod — $1695.**

Competing models include single-tine forks, spur-gear drives, and lightweight aluminum tripods suitable only for short-exposure planetary and terrestrial photos.

**Q: Is the Autostar hand controller included as standard equipment with the LX90? What telescope operations are enabled by the Autostar?**

**A:** The LX90's *standard-equipment* Autostar controller connects to the telescope's control panel and permits an incredible array of telescope options:

- Automatic GO TO capability at 6.5°/sec on both axes, simultaneously, to 30,223 database objects, including:

  13,235 deep-sky objects sorted by named objects; galaxies; diffuse nebulae; planetary nebulae; and star clusters; and including the complete Messier, Caldwell, IC, and NGC catalogs;

  16,888 stars sorted by name, SAO catalog numbers, double and variable stars; plus the centroids of the 88 constellations;

  50 objects in the solar system: 8 major planets from Mercury to Pluto; the Moon; 26 asteroids; 15 comets;

  50 Earth satellites, including the International Space Station, Hubble telescope, and Mir;

  plus 200 memory locations for user-defined objects.
- Automatic GO TO capability to *any* object of known R.A. and Declination.
- Nine selectable slew speeds: 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- Control of the telescope through your personal computer, using the RS-232 serial interface.
- Hundreds of special event menus, guided tours, glossary, utility functions, and telescope status options.
- Fast alignment of the telescope in either equatorial or altazimuth modes using any of three alignment functions, including the Meade-proprietary Easy Align*.
- Unlike the hand controllers included with competing 5" and 8" SCT's (and which require disassembly of the telescope electronics for memory upgrade), *Autostar is fully upgradeable over the Internet*: the observer can add the positions of new comets, update the positions of Earth satellites, even add new software as it becomes available.

*Patent pending.

**Q: How does the new 8" LX90 compare to the Meade 8" LX200? Which telescope should I buy?**

**A:** For a great many observers the 8" LX90 is all the telescope ever required. The LX90 includes the exact same 8" f/10 optical system, including coatings, as the 8" LX200, so that the visual observing experience is identical in both instruments. Notwithstanding the many virtues of the LX90, however, we still recommend the LX200 for those amateurs who can afford the slightly higher price of the LX200 and who intend an extensive program of CCD imaging, astrophotography, or deep-space observing. The LX200's object database, at 64,359, is more than twice the size of the LX90's, and the LX200 slews at 8°/sec to a pointing precision of 2 arc-minutes or better, compared to the 5 arc-minute pointing precision of the LX90. The LX200 mounting, with its oversize fork arms, larger worm gears, and Smart Drive™, is the most advanced altazimuth-equatorial platform ever offered in a production 8" Schmidt-Cassegrain. The real answer to the question is that one can not go wrong with either telescope: the proper choice depends on the user's long-term applications and budget.

AUTOSTAR
RA = 06:34.8
Dec = +66°48
MEADE
ENTER
MODE
GO TO
?

**The Autostar controller** facilitates hundreds of LX90 telescope operations at the push of a button and includes a database of more than 30,000 celestial objects.

**Q: How is the LX90 powered?**

**A:** Power at 12 volts DC is provided by (user-supplied) C-cell batteries loaded through the upper surface of the telescope's drive base. Alternately, the telescope may be powered from an automobile cigarette lighter plug or from a standard 115vAC home outlet, using optionally available power cords.

## Meade 8" LX90 at a Glance

| | |
|---|---|
| **Optics** | 8" f/10 Schmidt-Cassegrain |
| **Coatings** | Meade EMC Super Multi-Coatings |
| **Mounting** | Cast-aluminum, double-tine forks |
| **Gears** | 4.9"-dia worm gears, both axes |
| **Autostar Database** | 30,223 objects |
| **Alignment** | Altazimuth or equatorial, at user's option |
| **Pointing Precision** | 5 arc-minutes in GO TO mode |
| **Slew Speeds** | 1x sidereal to 6.5°/sec in 9 increments |
| **Slow-motion controls** | Electric, R.A. and Dec |
| **Tripod** | Variable-height field tripod |
| **Accessories** | 8 x 50mm finder, 1.25" diagonal prism, Super Plössl 26mm eyepiece |
| **Net telescope weight** | 31 lbs. |
| **Net tripod weight** | 20 lbs. |

**SPECIFICATIONS: 8" LX90** — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings; double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; operating instructions. **$1695.** Packing & shipping in the 48 states: $95.

Price shown is suggested U.S. mail-order retail price.

### *AUTHORIZED MAIL-ORDER DEALERS*

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**Orders: 800-422-7876; Info.: 405-364-0858.**

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# Astronomy®

**COVER PHOTO:** T. A. Rector, B. Wolpa, M. Hanna, KPNO 0.9-m Mosaic, AURA/NOAO/NSF

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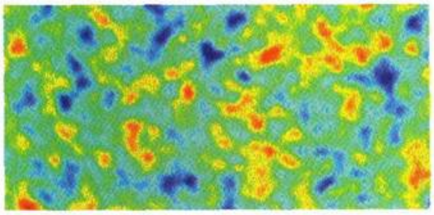

**40 1,000 Years of Unsung Astronomers**

Marie Larson

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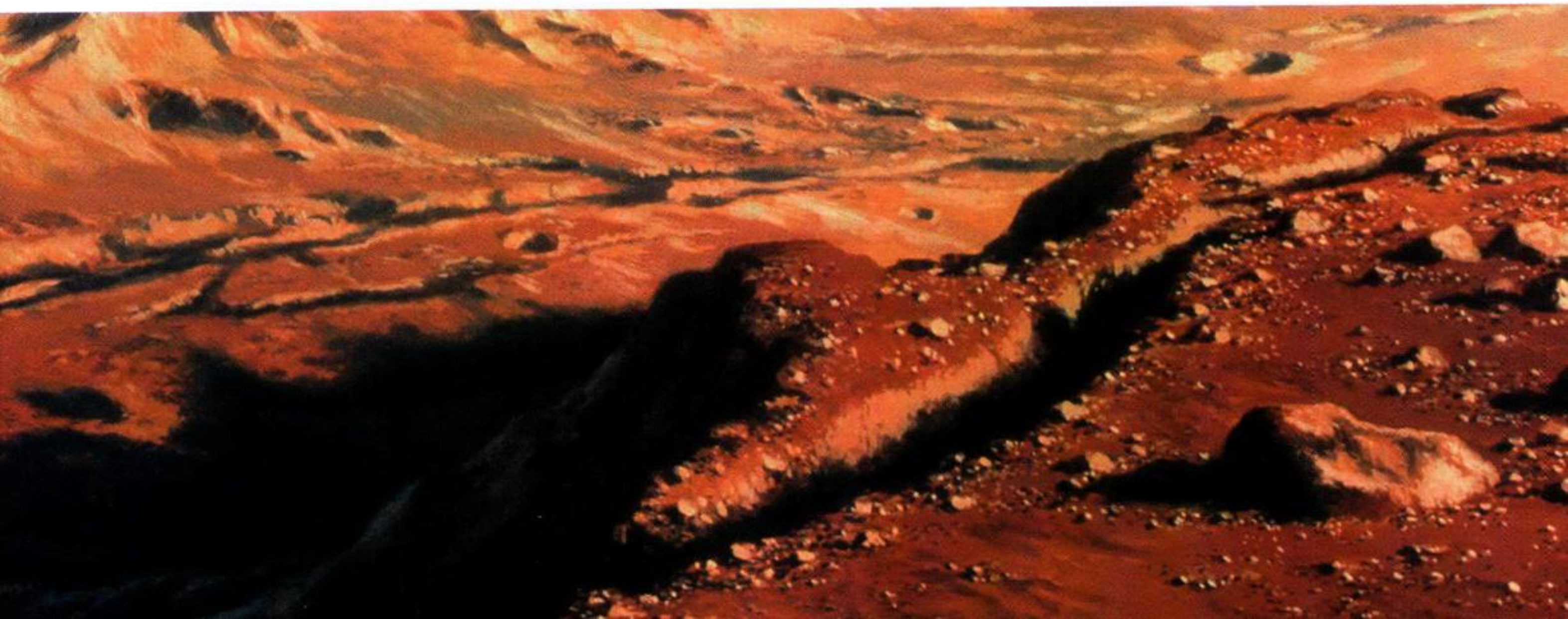

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

# A New Breed of Star Party

Two years ago our previous publisher, Russ Larson, had an idea for a new kind of star party; his idea has taken hold, and this summer it will begin to flower on August 4 and 5. We will kick off our public star parties in the city of Davis, California, within driving distance of both Sacramento and San Francisco. And we are especially proud to be bringing in guests whose dazzling presentations will keep you wide awake during daylight hours. The party begins on Friday night with a keynote talk by supernova guru Alex Filippenko who will give us the low-down on the heavens' grandest explosions. At the Davis Veterans Memorial Center, other speakers for Friday and Saturday include *Astronomy* contributing editor Ray Jayawardhana, member of the Harvard team that recently discovered a newly forming extrasolar planetary disk; and Seth Shostak, who will bring us up to date on the search for intelligent life in the universe. We will also bring in speakers from the Jet Propulsion Laboratory's Mars team and from the NASA Ames astrobiology group. A panel of highly respected science writers, photographers, and illustrators will answer your questions about how they cover the subject of astronomy.

*Astronomy*/Alan Dyer

**Star parties open up a new world.**

We are planning to throw a totally new kind of star party on Saturday night. Our co-sponsors, the Northern California Astronomy Clubs and the Davis Visitors and Convention Center, will work with telescope manufacturers and retailers to set up learning stations that will allow you to see the sky in new ways. They will be sharing the latest go-to telescopes as well as lots of homegrown Dobsonians.

The big difference between this star party and all others is that we will come prepared with maps and guides. Scopes will be set at clearly marked stations, and teachers will be at each station to help you use the telescopes and understand what you are seeing. Each station will focus on one category of sky object: planets, moon, double stars, galaxies, or nebulae. Hosts will be looking out for stragglers, and there will be printed material to take home with you. Exhibitors will include telescope makers, optics manufacturers, space artists, and photographers who will have things to sell that you might cherish.

As the largest, finest astronomy magazine, we want to share our passion with newcomers. *Astronomy* staffers will be on hand to introduce speakers, meet participants, and take turns at the telescopes. Together, we've got more than 200 years of observing experience, and we hope to share it. And for those who can't make California, we will be coming to your state soon.

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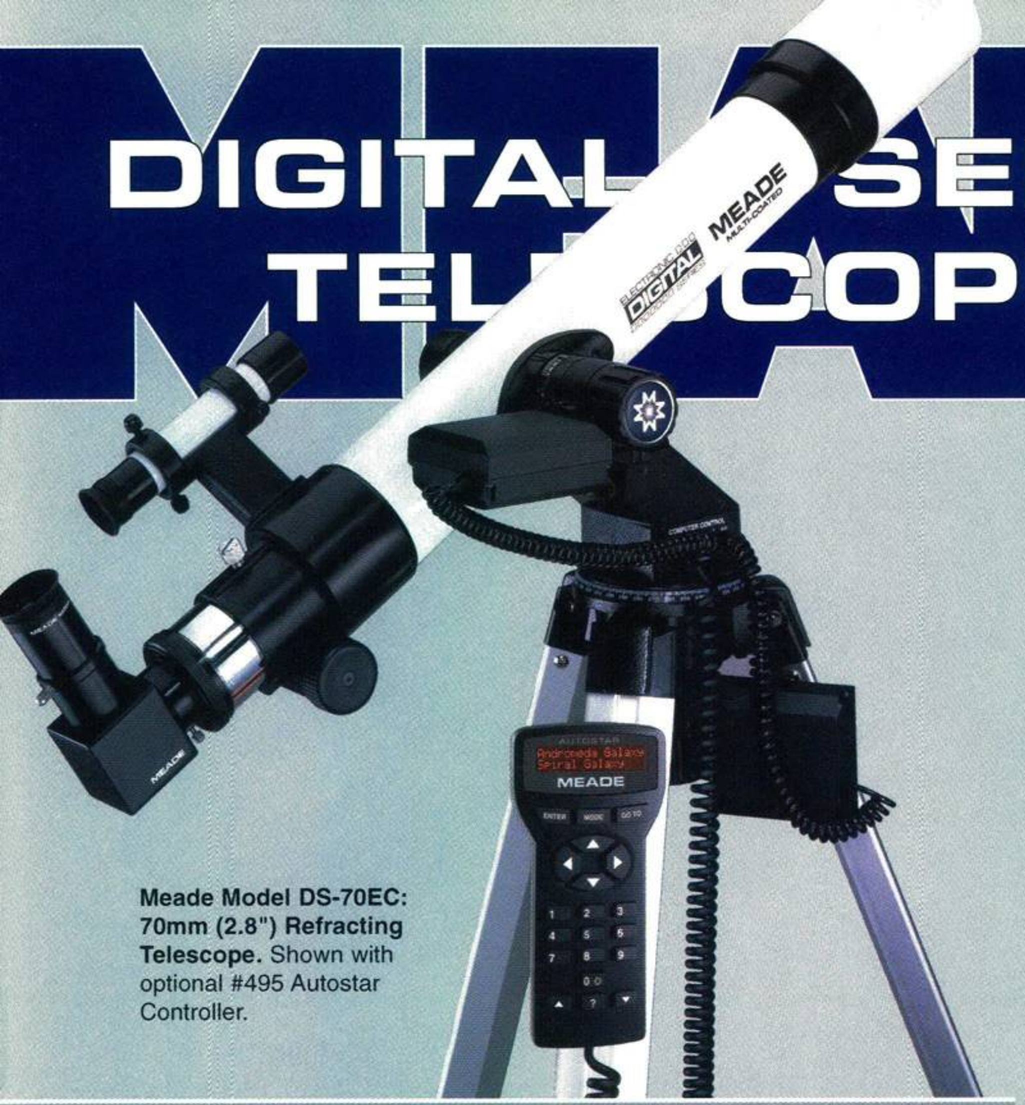
# MEADE DIGITAL SERIES TELESCOPES



**Meade Model DS-70EC: 70mm (2.8") Refracting Telescope.** Shown with optional #495 Autostar Controller.

Meade Digital Series (DS) Telescopes offer the widest range of features ever made available in telescopes of their price class. The standard-equipment Electronic Controller (EC) permits precise pushbutton slewing and tracking at any of four speeds. Available optionally, the #495 Autostar Controller allows for automatic GO TO operation.

## Digital Electronic Series Telescopes by Meade®: High Technology, Low Prices.

Now even the beginning or casual observer can enjoy the benefits of the very latest in digital microprocessor technology. Meade Digital Series (DS) telescopes are a revelation of electronic capability, premium-grade optics, and mechanical precision.

**Electronic Controller:** Use the Electronic Controller, provided as standard equipment with all DS-EC models, at any of four dual-axis speeds from 2 arcmins/second to 6°/second, to center and track astronomical objects at any magnifying power.

**Altazimuth Mountings:** Engineered for smooth dual-axis tracking, Digital Series altazimuth mounts provide a level of mechanical precision previously unavailable on beginning- and intermediate-aperture telescopes.

**Optical Systems:** Meade DS refracting telescope models include 2-element mulit-coated achromatic objective lenses, precision polished from crown and flint optical glass components. Newtonian reflecting telescopes of the series include primary and secondary mirrors free of the optical zones and irregularities often found on optics of lesser quality.

**Optional #495 Autostar Controller:** Plug in the Meade #495 Autostar Controller to the control panel of your DS-EC telescope, and you're ready to locate any of over 1500 celestial objects in the Autostar database, including hundreds of galaxies, nebulae, star clusters, the complete Messier and Caldwell deep-space catalogs, and more — all at the push of the GO TO button.

IN
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OUT
SPEED
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MEADE

The standard-equipment Electronic Controller of Meade DS-EC models.

**Specifications:** Each Meade Digital Series telescope described here is *supplied complete* as shown in the photo below, with aluminum field tripod, two eyepieces (1.25"), diagonal mirror, 5 x 24mm or 6 x 30mm finder, Electronic Controller with dual-axis motors, and battery pack (accepts ten AA-size user-supplied batteries.) *See the Meade General Catalog for complete specifications.*

### MEADE DIGITAL SERIES TELESCOPES

| | |
|---|---|
| DS-60EC: 60mm (2.4") Refractor | $299 |
| DS-70EC: 70mm (2.8") Refractor | 349 |
| DS-80EC: 80mm (3.1") Refractor | 449 |
| DS-90EC: 90mm (3.5") Refractor | 499 |
| DS-114EC: 114mm (4.5") Reflector | 399 |
| DS-127EC: 127mm (5.0") Reflector | 449 |
| #495 Autostar for any above model | 99 |

Prices shown are suggested U.S. mail-order retail prices. Patents pending on DS systems architecture and Autostar.

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*Left-to-right:* Meade DS-60EC, DS-70EC, DS-80EC, DS-90EC, DS-114EC, DS-127EC

New Low Prices!

# MEADE LX200

## 8" LX200 $2295

## 10" LX200 $2695

## 12" LX200 $3995

### The largest-selling serious telescopes in the world are now available at the most affordable prices *ever!*

The exact same LX200's as before: not one specification has been changed. **Compare a Meade LX200 feature-for-feature with competing single-tine-fork, spur-gear-driven, GO TO Schmidt-Cassegrains.** You'll see why there really is no comparision:

- **Superb Optics:** With oversize primary mirrors for greater full-field illumination, LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Competing 8" Schmidt-Cassegrains claim to place objects "somewhere in the field of view;" Meade LX200's place objects **dead-center** in the field of view, first time, every time, to a pointing precision of **2 arc-minutes or better,** or, with Meade-exclusive High Precision Pointing, to a precision of **one arc-minute or better.** *Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any object in the onboard database, to these levels of precision.*
- **Database of 64,359 Objects,** a database *more than three times larger* than competing GO TO telescopes.
- **Permanently-Programmable Smart Drive**™ routinely achieves 5 arc-sec. periodic error, an observatory standard. Competing GO TO 8" SCT's decline to state their periodic error and do not offer any programmable error-corrector.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every contingency of telescope posi-

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MEADE LX200 EMC
MEADE LX200
SMART DRIVE
Meade
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**Meade 8" LX200 Schmidt-Cassegrain Telescope — now $2295, complete.**

tioning — from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between. Competing 8" SCT's slew only up to 6.5°/sec.

- **Rigid LX200 Dual-Tine Fork Mountings with Dual 5.75" Worm Gears** are the choice of advanced observers, CCD imagers, and astrophotographers for their most sensitive applications. Competing spur-gear-driven single-tine forks can not approach the strength, rigidity, and drive-rate precision built into every Meade LX200 mounting.

- **Full Long-Exposure Capability:** Competing 8" GO TO telescopes describe their capability to take short-exposure "planetary and terrestrial photos," without reference to any long-exposure capabilities. Meade LX200's have been the instruments of choice in **thousands** of the most detailed long-exposure images ever taken by amateur astronomers.

- **Strong Field Tripods:** Unlike the thin, extruded aluminum tripods of competing models, every LX200 includes a fully adjustable steel field tripod perfectly suited to the sub-arc-second resolution of the telescope's optics.

---

*"...Viewing a 2nd-magnitude star at high power [the 8" LX200] showed a nearly textbook-perfect image...I do indeed rank these optics as diffraction limited...Jupiter and Saturn exhibited riveting detail... During the November 10, 1997, triple shadow transit on Jupiter, the LX200 was my telescope of choice. It showed all three moon shadows as plainly different in size and shading, a rare and remarkable sight. Under the automatic GO TO command, the LX200 routinely placed objects, including the Moon and planets, within 1 to 4 arc-minutes of the center of the field. Not only was it accurate — it was fast. The LX200 usually took no longer than 10 to 25 seconds to slew to and center an object...The latest major feature added to the system is what Meade calls High Precision Pointing. When this is activated...Meade promises a pointing accuracy of 1 arc-minute. I can confirm this amazing figure. Objects consistently ended up within 1 to 2 arc-minutes of the field's center, a great aid to CCD imaging of faint targets...if you know what you want to look at, the LX200 will find it with astonishing speed and accuracy...the telescope I tested provided excellent performance in all critical areas while adding a level of technical luxury that is truly powerful and impressive...I have absolutely no hesitation in recommending the LX200 series...After having used the LX200 for several months, I can attest to the wonderful hands-off convenience and sheer fun of the motorized GO TO."* — **from the review in *Sky & Telescope,* April, 1998.**

---

*"The [10" LX200] telescope's optics, stability, and tracking accuracy — all of which are crucial in my applications — are truly remarkable, fully up to the demands that my photographic program requires. My LX200 is now nearly four years old, and during that time it has received heavy use, including 2000-mile round trips to southern France four times a year. The telescope is everything I could possibly have expected it to be."* — **Philip Perkins, Wiltshire, England**

**The Whirlpool Galaxy (M51) in Canes Venatici.**
A 10" LX200 photo by Philip Perkins; two 120-minute exposures were digitally combined to obtain the final image.

*"The view through the [7" LX200] system is superb, with pin sharp images right across the field and absolutely no trace of achromatism. Moving to higher powers reveals stellar images constrained only by the seeing and limitations of diffraction.... This telescope is, by any standards, a most powerful observing system.... If you were to sit down and write a specification based on unbridled optimism and imagination, I doubt whether you would come up with all of the features available on the LX200 series. This telescope really has to be experienced."* — **from the review in *Astronomy Now (U.K.),* November, 1996, by Bob Neville, Director, Instruments and Imaging Section, British Astronomical Association.**

---

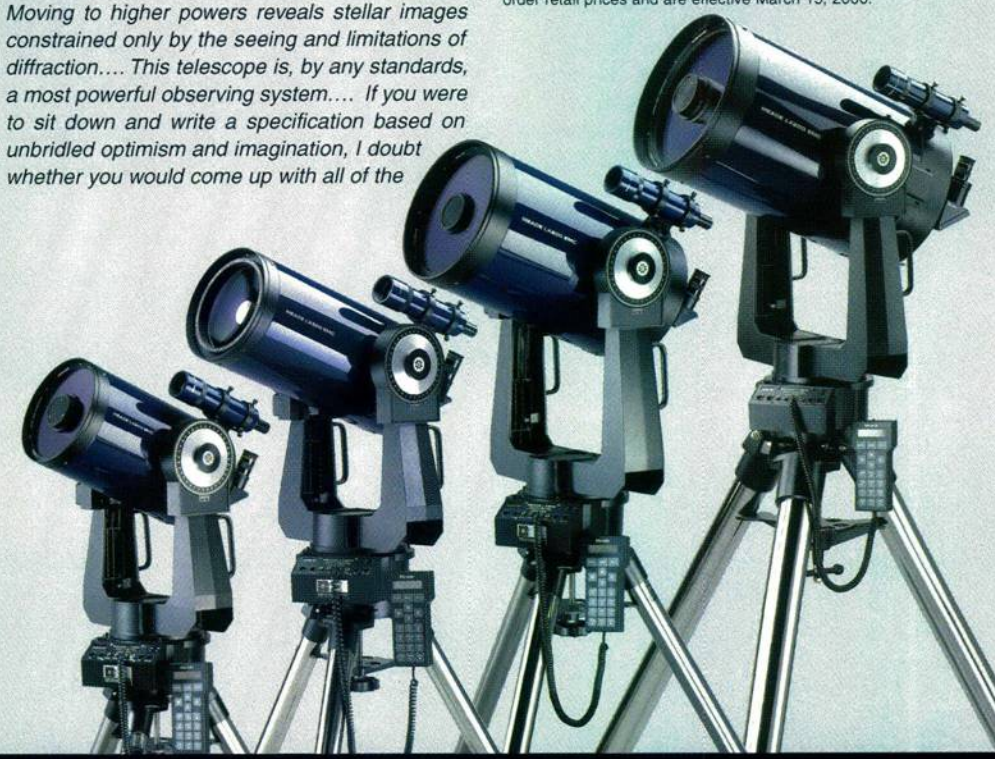
*"The optics of my 12" LX200 are exquisite — in fact the best optics in a commercial catadioptric telescope that I have ever looked through. At 500X the Epsilon Lyrae double-double is not only clearly split into four components, but each of the four stars exhibits a textbook-perfect diffraction pattern, the ultimate test for superior optics."* — **Jack Newton, Chiefland, FL.**

---

**SPECIFICATIONS: 7", 8", 10", and 12" LX200's** — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

| | |
|---|---|
| **8" LX200 Schmidt-Cassegrain** | **$2295.** |
| **10" LX200 Schmidt-Cassegrain** | **2695.** |
| **12" LX200 Schmidt-Cassegrain** | **3995.** |
| **7" LX200 Maksutov-Cassegrain** | **2795.** |

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125. Prices shown are suggested U.S. mail-order retail prices and are effective March 15, 2000.



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**Meade Instruments Corporation**

*World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur*

6001 Oak Canyon, Irvine, California 92618 ■ (949) 451-1450
FAX: (949) 451-1460 ■ *www.meade.com*

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**New!**

# Now you can join the ETX revolution for as little as $299, complete!

Let Meade high-resolution ETX optics and standard-equipment Autostar controller take you on an automated guided tour of the Solar System, the Galaxy, and beyond. Now even the most novice amateur astronomer can locate and explore the planets, asteroids, and comets, as well as nebulae, star clusters, galaxies, and hundreds of other deep-space objects, at the push of a button.

**Fork Mount with Dual-Axis Drive System:** In conjunction with the Autostar hand controller, precision worm gear systems on each axis permit smooth pushbutton motions of the telescope, as well as sidereal-rate tracking in the altazimuth mode.

**Standard-Equipment #494 Autostar™ Controller:** The #494 Autostar includes most of the same features as the more advanced #497 Autostar available for larger Meade ETX models *(facing page).*

- **Automatic dual-axis GO TO function at 4.5°/sec.** to any of more than 1450 database objects, including the complete Messier and Caldwell deep-space object catalogs, the major planets from Mercury to Neptune, 26 asteroids, 15 periodic comets, and more.
- **Select any of Autostar's** database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field of view.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 4.5°/sec., plus sidereal-rate tracking.

**High-Resolution Achromatic Objective Lenses:** ETX 60mm and 70mm models include multi-coated air-spaced achromatic lenses of exclusive Meade design; each lens yields razor-sharp images of astronomical and terrestrial subjects.

**Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #933 45° Erecting Prism or for photography with the optional #64ST Photo Adapter.

**Cordless Operation:** The dual-axis drive of Meade ETX-60AT and ETX-70AT models operates for over 20 hours in the field from six AA-size (user-supplied) batteries which store neatly inside the drive base.

MEADE
ETX-60AT • ETX-70AT
MEADE
COMPUTER CONTROL
Guided Tour
Tonight's Best
ENTER
MODE
GO TO
SPEED
MEADE
AUTOSTAR
Solar System:
Saturn
ENTER
MODE
GO TO
SPEED
MEADE
AUTOSTAR

**ETX-70AT: $349,** complete with #494 Autostar Controller

**ETX-60AT: $299,** complete with #494 Autostar Controller

**SPECIFICATIONS: ETX-60AT and ETX-70AT Astro Telescopes** — Each includes achromatic refractor optical tube assembly (D = 60mm, F = 350mm, f/5.8 *or* D = 70mm, F = 350mm, f/5) with multi-layer optical coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles, and locks on both axes; electronic control panel; 9-speed (2x sidereal through 4.5°/sec.) dual-axis motor drive system with #494 Autostar computer controller; sidereal-rate tracking; internal battery compartment accepting six (user-supplied) AA-size batteries; MA9mm (39X) and MA25mm (14X) multi-coated eyepieces; operating instructions. **ETX-60AT — $299** (+$10 packing & shipping in the 48 states); **ETX-70AT — $349** (+$10 P & S).

**OPTIONAL SYSTEMS FOR MEADE ETX TELESCOPES***

| | | | |
|---|---|---|---|
| #882 Standard Field Tripod (60, 70) | $99.00 | #883 Deluxe Field Tripod (90, 125) | 199.95 |
| #827 8 x 25mm Right-Angle Viewfinder (60, 70) | 49.95 | #825 8 x 25mm Right-Angle Viewfinder (90) | 49.95 |
| #773 Hard Carry Case (60, 70) | 59.95 | #774 Hard Carry Case (90) | 99.95 |
| #933 45° Erecting Prism (60, 70) | 49.95 | #775 Hard Carry Case (125) | 149.95 |
| #64ST Photo Adapter (60, 70) | 19.95 | #932 45° Erecting Prism (90, 125) | 49.95 |
| #497 Autostar Computer Controller (90, 125) | 149.00 | #64 Photo Adapter (90, 125) | 34.95 |
| #880 Equatorial Table Tripod (90) | 29.95 | Electric Focuser #1244 (90) *or* #1247 (125) | 119.95 |
| #881 Equatorial Table Tripod (125) | 59.95 | | |

**see also the Meade accessory ad in this issue.*

**MEADE INSTRUMENTS CORPORATION** *The largest-selling telescopes in the world.*

# MEADE ETX-90EC • ETX-125EC

COMPUTER CONTROL
MEADE
IN
FOCUS
OUT
SPEED
MODE

ETX-90EC: $595, complete with Electronic Controller

ETX-125EC: $895, complete with Electronic Controller

## Two advanced apertures: ETX-90EC — $595 ETX-125EC — $895

Meade® 3.5" and 5" ETX® models include the very latest in microprocessor-controlled capability:

**Fork Mount with Dual-Axis Drive System:** Each with high-torque DC motors on both telescope axes, permitting electronic operation from the standard-equipment plug-in hand controller.

**Pushbutton Electronic Hand Controller:** Use at any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power or for pushbutton object-tracking in the altazimuth mode; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

**Maksutov-Cassegrain Optical Systems:** Manufactured at the Meade Irvine, facility, ETX diffraction-limited optics produce images so high in contrast and resolution that ETX telescopes often outperform other telescopes of larger apertures.

**Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

**Cordless Operation:** The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

**Optional #497 Autostar™ Capability:** Plug in the optional Meade #497 Autostar computer controller for LX200-type operation, including:

- **Automatic dual-axis GO TO function at 5°/sec** to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; and more.
- Select any of Autostar's database objects, *or any* object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.
- **Digital readouts** of telescope position, continuously in R.A. and Dec.
- **9-Speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec., plus sidereal-rate tracking.

ETX AUTOSTAR
MEADE
ENTER
MODE
GO TO

**SPECIFICATIONS: ETX 90EC and ETX-125EC Astro Telescopes —** Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $595** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

*AUTHORIZED U.S. AND CANADA MAIL-ORDER DEALERS*

**ASTRONOMICS, Norman, OK.**
**Orders: 800-422-7876; Info.: 405-364-0858.**

**FOCUS CAMERA, Brooklyn, NY.**
**Orders: 800-221-0828; Info.: 718-436-6262.**

**LUMICON, Livermore, CA.**
**Orders: 800-767-9576; Info.: 925-447-9570.**

**OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.**
**Orders & Information: 800-483-6287.**

**POCONO MOUNTAIN OPTICS, Moscow, PA.**
**Orders: 800-569-4323; Info.: 570-842-1500.**

**RIVERS CAMERA, Dover, NH.**
**Orders: 800-245-7963; Info.: 603-742-4888.**

**SHUTAN CAMERA & VIDEO, Chicago, IL.**
**Orders & Info.: 800-621-2248; IL: 847-367-4600.**

**KHAN SCOPE CENTRE, Toronto, Ontario.**
**Orders & Information: 416-783-4140.**

6001 Oak Canyon, Irvine, CA 92618. (949) 451-1450. FAX: (949) 451-1460. www.meade.com

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# RESEARCH-GRADE ACCESSORIES

## Series 4000™ Super Plössls
## 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

**Super Plössls** (SP; 4-elements; 1.25"; 52°):

**6.4, 9.7, 12.4, 15, 20, 26mm** each: **$79.95** (4.54)

**32mm** (52°); **40mm** (44°) each: **99.95** (5.26)

**56mm** (52°; 2") **199.95** (7.02)

## Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

**Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

## Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

## 2x Telenegative Barlow (1.25")

**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (4.54)

## 2x Short-Focus Barlow (1.25")

**#126:** Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25". **$59.95** (4.54)

## 2" Diagonal Mirror

**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

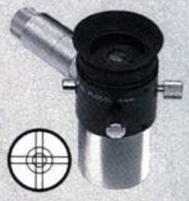
**#929** or **#930,** each: **$99.95** (6.85)

## 45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

**$42.95** (3.86)

## World's Most Advanced Illuminated Reticle Eyepiece



**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

**$129.95** (5.26)

**Series 4000 Photo-Visual Color Filters** (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

**#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue** each **$14.95** (2.73)

**Set #1**–4 filters: #12, #23A, #58, #80A **49.95** (4.54)

**Set #2**–4 filters: #11, #25A, #47, #82A **49.95** (4.54)

**Set #3**–4 filters: #8, #21, #38A, #56 **49.95** (4.54)

**Series 4000 Moon Filter (#ND96):** Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

## #905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

## Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

**#1206 Electric Focuser:** Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

**#1205 Electric Focuser:** For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery. **$169.95** (7.88)

## #777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

**$79.95** (6.85)

## Series 4000™ 2x Apochromatic Barlow Lens

**#140:** The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

## Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

**Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

## Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

**Series 3000 Plössls** (4-elements; 1.25"; 50°)

**5, 6.7, 9.5, 16, 25mm** each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

**Series 4000 Nebular Filters**—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

**#908B**–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)

**#910B**–Threads into 2" eyepieces, 44mm dia. **119.95** (5.26)

**#911B**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)

**#908N**–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)

**#910N**–Threads into 2" eyepieces, 44mm dia. **129.95** (5.26)

**#911N**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

#911X
#910X
#908X

**Series 4000 Oxygen-III Filters** Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

**#908X**–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)

**#910X**–Threads into 2" eyepieces, 44mm dia. **159.95** (5.26)

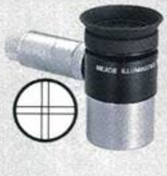
**#911X**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **149.95** (5.26)

## Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

## MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

**$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

## Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

**.965": $27.95**; **1.25": $29.95** (3.86)

## Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

**$39.95** (3.86)

## Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

**$39.95** (3.86)

## T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

**$26.95** (3.86)

## CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

*"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope."* — Jack Newton

**#644 Flip-Mirror System:** Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

**#647 Flip-Mirror System:** Accepts either 1.25" or 2" eyepieces. Mirror clear aperture 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

**#157 1.25" Adapter:** Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!

## Epoch 2000® Sky Software

### The most powerful astronomical software ever made available can now be yours for only $149!

**Epoch 2000sk** *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

**Epoch 2000ip Image Processing Software** *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

**EPOCH 2000sk Sky Software:** 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . . . **$149**

**EPOCH 2000sk-CD Sky Software:** 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM . . . . . . . . **179**

**LX200 Interface Cable:** for Meade LX200 operation by Epoch 2000sk . . . . . . . . **25**

**EPOCH 2000ip Image Processing Software:** Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . . . . . **$199**

## Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

## Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

## #825 8 x 25mm Right-Angle Viewfinder for ETX-90

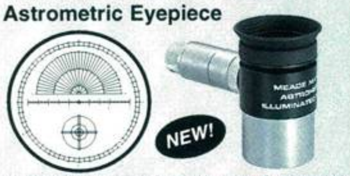
NEW!

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

## #64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

## MA12mm Illuminated Reticle Astrometric Eyepiece



NEW!

A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

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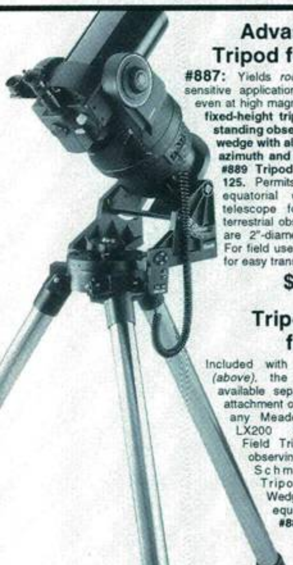

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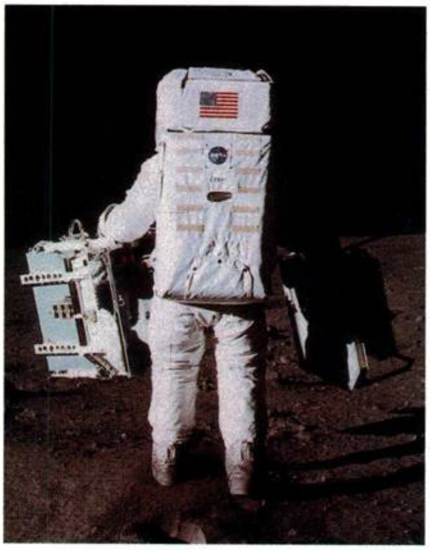
# Reality in Space

Reader Troy Boyle writes in the April 2000 issue of his passion for the exploration of space. He remembers vividly the Apollo era, imagined Neil Armstrong "jouncing along in the moon buggy," and now is "disillusioned and depressed" over NASA's floundering space program. He wonders "where the spirit of discovery and the iron will of mid-century America" have gone.

I, too, watched the first moon landing on television as a child and dreamed of going there myself. As an adult, however, I have come to realize that the passions that drive people to explore the great unknowns are not primarily the thirst for adventure. More often, it is a significant social, religious, or political circumstance that causes humans and nations to invest huge amounts of money and risk their fates in search of the unknown.

Take Columbus, for example: Deeply committed to the spread of Christianity, he was convinced that if the world were really a sphere, it would be much easier (and safer) to get missionaries to the Far East by sailing west. More than a century after Columbus rediscovered America, European colonization began, first for religious reasons, and later for economic purposes.

Our journey to the moon had equally nonscientific roots. America's space program was based on developing airplanes that could reach outer space and land on runways. When the USSR successfully orbited Sputnik in 1959, Americans panicked. Military aviation was at the point where, if you controlled the skies, you controlled the battle. Sputnik showed the United States that the Soviets were ready to take control of the skies, and the most obvious symbol of that would be landing on the moon. Thus, the space race was on. It wasn't about adventure, or even about science. It was about war.



**Apollo 11 astronaut Edwin E. Aldrin, Jr., deploys lunar experiments.** NASA

Today the Cold War is over. Some say the United States won. In fact, the whole world won. We didn't nuke ourselves. America is still here. Russia is still here. And so is everyone in between. The technologies and discoveries that came as a result of the Cold War (and the space programs) have changed our lives tremendously, and will continue to do so.

Science didn't get Europe to the Americas. Religion did. Adventure didn't get man to the moon. Communism did. While I admire Mr. Boyle's passion for discovery and adventure, I'm afraid that his plan to grab the whole world and "shake it and scream, 'Wake up! The universe is ours!' " will not work. It never has. What we really need is another crisis. — *Ron Mattson, Braidwood, Illinois*

### Airbag Redux

I'm still troubled by the loss of the Mars Polar Lander. And, I empathize with the scientists, researchers, and students who poured their hearts and souls into that project. So tell me: What was wrong with the airbags? — *Nick Giovanni, Bremerton, Washington*

*Good question, but don't fault NASA too much. In 1997, the Mars Polar Lander project was already underway as Pathfinder bounced to a spectacular landing on Mars. Too late to make any major modifications in the MPL, NASA instead counted on the proven landing methods used on the two successful Vikings missions of the 1970s. Reverting to a landing technology that worked well in the past was not seen as a design flaw.* — *Astronomy* editors

### Adaptive Accomplishment

I would like to congratulate Mark Sincell for his excellent effort (See "Making the Stars Stand Still," June 2000) on the fascinating and exciting history behind one of the great revolutions in astronomy: adaptive optics. Fugate's accomplishments, as well as the electrifying and dramatic impact of his work on the community, beg for a full-length book. If there is a shortcoming to Sincell's article, it is that it does not — and probably cannot — begin to portray the nearly unimaginable challenges and obstacles (especially the "nontechnical" ones) that Fugate surmounted to turn a theoretical dream into reality. Fugate and his team possess a rare and special blend of genuine technical depth and ability, combined with a clear and unobstructed vision and energy, good humor and relentless tenacity. An axiom in the highly competitive government research environment holds that the only thing harder than getting money for a project is keeping it. That Fugate managed to succeed in such an environment is even more remarkable than had he done it from the private or academic sector. Adaptive optics became real not because of SDI, but because of the incredible vision, dedication, and unrelenting drive of Fugate and his team. For that, we are all deeply in his debt. Many thanks to Mark Sincell for profiling this awesome accomplishment. — *Gregory D. Peisert, Dayton, Ohio*

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### Stereotyped Aliens

Why oh why did you have to lend support to believers in UFOs and alien contact? (See "SETI and the Science Wars," May 2000.) The legitimate science of SETI already suffers from such pseudoscientific associations. Few, if any, biologists believe that extraterrestrials will look anything like the almond-eyed humanoids now in vogue with unimaginative *X-Files* fans. Am I the only one annoyed by the appearance of anthropomorphic "aliens" in a science magazine? — *Jamie Bechtel, Omaha, Nebraska*

### Strangest Omission

My 12-year-old son, an avid reader of *Astronomy*, told me about "Strangest Matter" (April 2000) while we were outside exercising. When I asked him about the statistical odds of a piece of cosmic shrapnel hitting us directly, he looked puzzled.

Can one of these elusive and feisty strange quark-matter pieces hit us on the head? Please, someone tell us if we run a risk of getting bopped by one of those "Strange Matter" pieces you wrote about at such length. — *Shannon Casey, Duluth, Minnesota*

*Have no fear — the flux of hypothetical strange-matter particles is extremely small. Nevertheless, if someone would get hit by a strange particle, it would pass through the body (and even buildings, for that matter) without restraint — eventually getting stuck somewhere in the interior of Earth. We all get hit countless times (specifically on airplanes) during our life by "ordinary" atomic particles that are cosmic rays, which constantly strike Earth at a much greater rate. And we all seem to be getting along with it pretty well.* — Fridolin Weber, Lawrence Berkeley National Laboratory, Berkeley, California **A**

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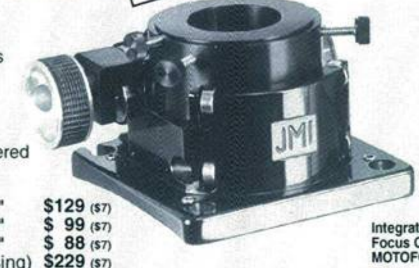

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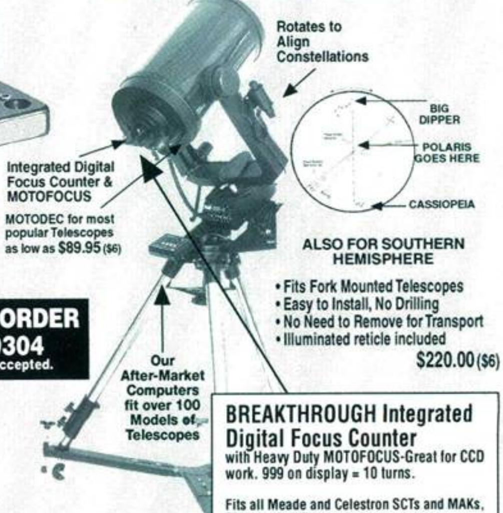
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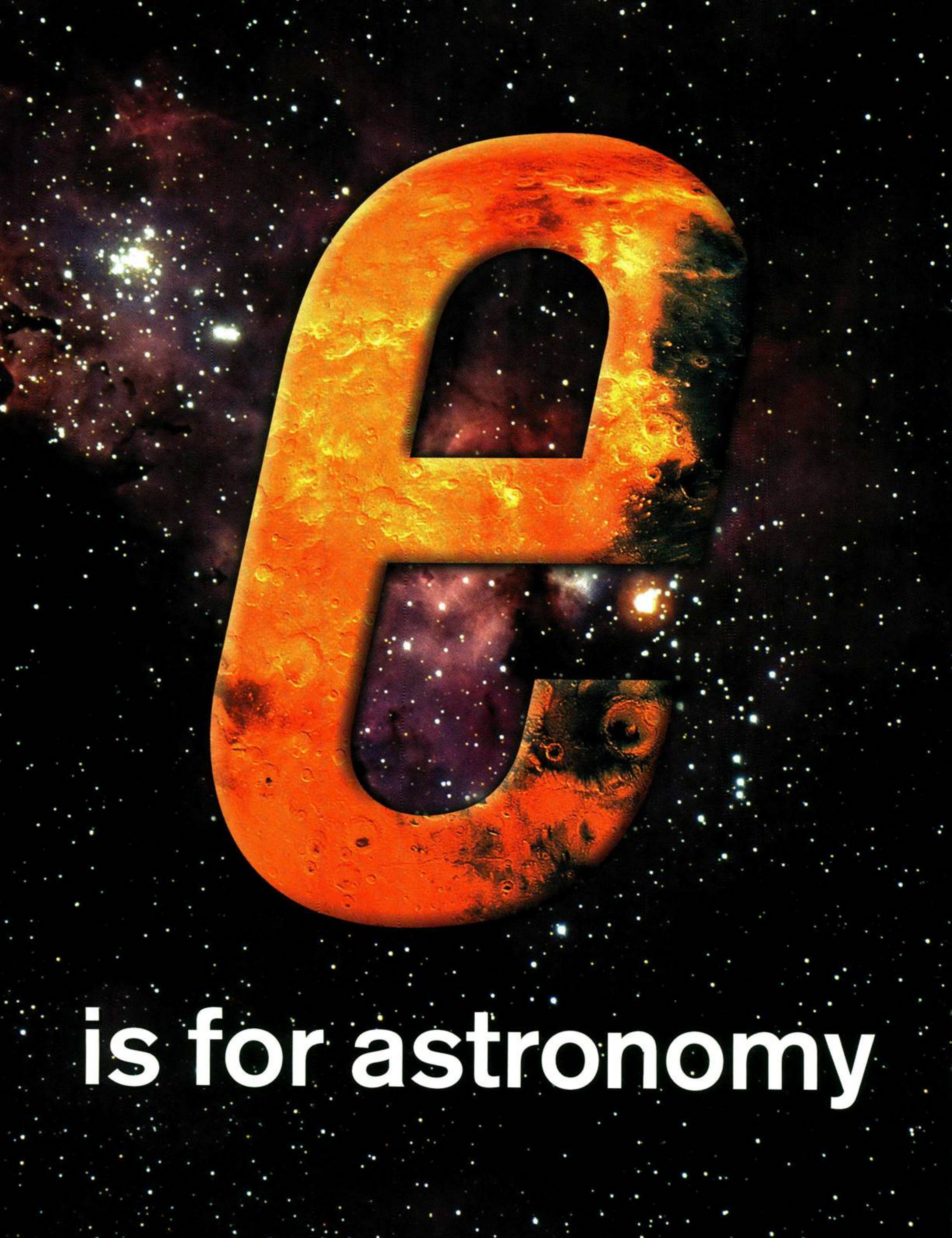
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COSMOLOGY

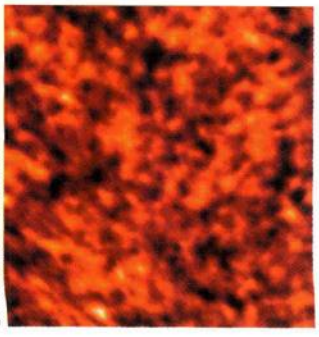
# Balloon Flight Points to Flat Universe

▶ Somewhere in the great beyond, Euclid must be smiling. A balloon flying over Antarctica has shown that space is flat, not curved, just as the Greek geometer would have expected.

The mission, called BOOMERANG (Balloon Observations of Millimetric Extragalactic Radiation and Geophysics), soared high around the South Pole for 10 days in December 1998 and January 1999. It carried a 1.2-meter telescope that measured the faint glow from space known as the cosmic microwave background. This is a remnant of the searing heat of the Big Bang, which cosmologists believe created the universe 12 to 15 billion years ago.

An Earth-orbiting satellite called COBE (Cosmic Background Explorer) spied subtle ripples in this glow in 1992. The ripples revealed that the Big Bang was not perfectly uniform. Rather, tiny fluctuations made some parts of the expanding fireball hotter and other parts colder. Those patterns became seeds for the clusters of galaxies we see throughout the universe today.

**Temperature fluctuations of less than 1/1000 of a degree (shown in shades of orange) spaced 1°apart suggest that the universe is flat.**



BOOMERANG Collaboration

BOOMERANG Collaboration

**Mount Erebus provides a unique background as scientists ready the BOOMERANG experiment for its 1998 launch from Antarctica.**

Now BOOMERANG has recorded the temperature ripples with 40 times more detail than COBE, says mission coleader Andrew Lange, an astrophysicist at the California Institute of Technology. "These are the first clear images of the embryonic universe," Lange says. "These are literally snapshots of what the universe looked like when it was just a few hundred thousand years old." Lange and his international team published their results in the April 27 issue of *Nature.*

The details of the temperature pattern match a key prediction of "inflation," a scenario in which the universe grew extraordinarily quickly in the first fraction of a second after the Big Bang. According to cosmological models, inflation stretched the fabric of space violently and eliminated its curvature — like the surface of a beach ball blown up to a vast scale. "The pattern of hot and cold spots on the sky is undeniably that of a flat universe," says cosmologist Michael Turner of the University of Chicago.

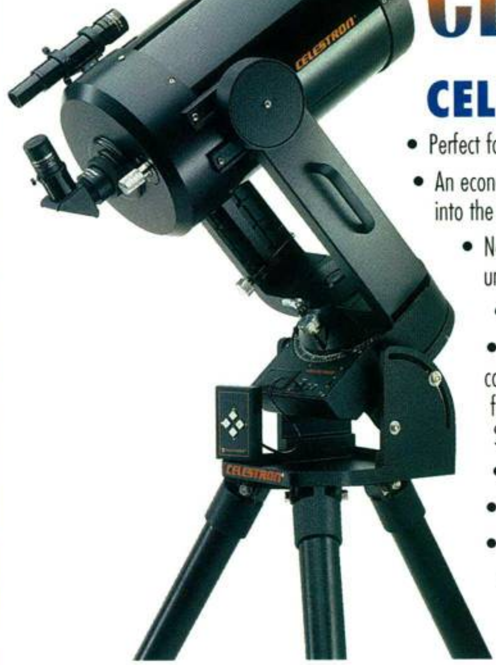
This three-dimensional flatness is hard to picture. Most simply, it means that two parallel beams of light will always stay parallel rather than curving toward or away from each other. Other models of the early universe had suggested that space still could be curved. But if it was, the curvature would have shrunk or expanded the temperature pattern BOOMERANG saw.

A flat universe requires a special cosmic recipe of matter and energy. Astronomers can account for only 5 percent of this recipe as stars, galaxies, and the matter that composes the Earth and us. Perhaps 30 percent exists as dark matter, unknown particles that surround galaxies in massive shrouds.

BOOMERANG's results suggest that most of the recipe, about 65 percent, is in the form of "dark energy" — a strange repulsive force that permeates space and makes the universe expand faster with time. For more on these and other recent cosmological discoveries, see "Unveiling the Flat Universe" on page 46.

— ROBERT IRION

# CELESTAR 8 TELESCOPES



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- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90.°
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.

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- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
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GALACTIC ASTRONOMY

# Filling the Brown Dwarf Gap

▶ Goldilocks would be happy with three newly discovered brown dwarfs. Just like her porridge, they're neither too hot nor too cold — they're just right.

The three brown dwarfs fill in what had been an annoying "missing link" in brown dwarf temperatures. Until May 2000, astronomers had found about 100 hot brown dwarfs with temperatures between 1500 and 3500 kelvins and a dozen or so cool brown dwarfs with temperatures between 800 and 1000 kelvins. The three new brown dwarfs nicely bridge the gap, with temperatures between 1000 and 1500 kelvins.

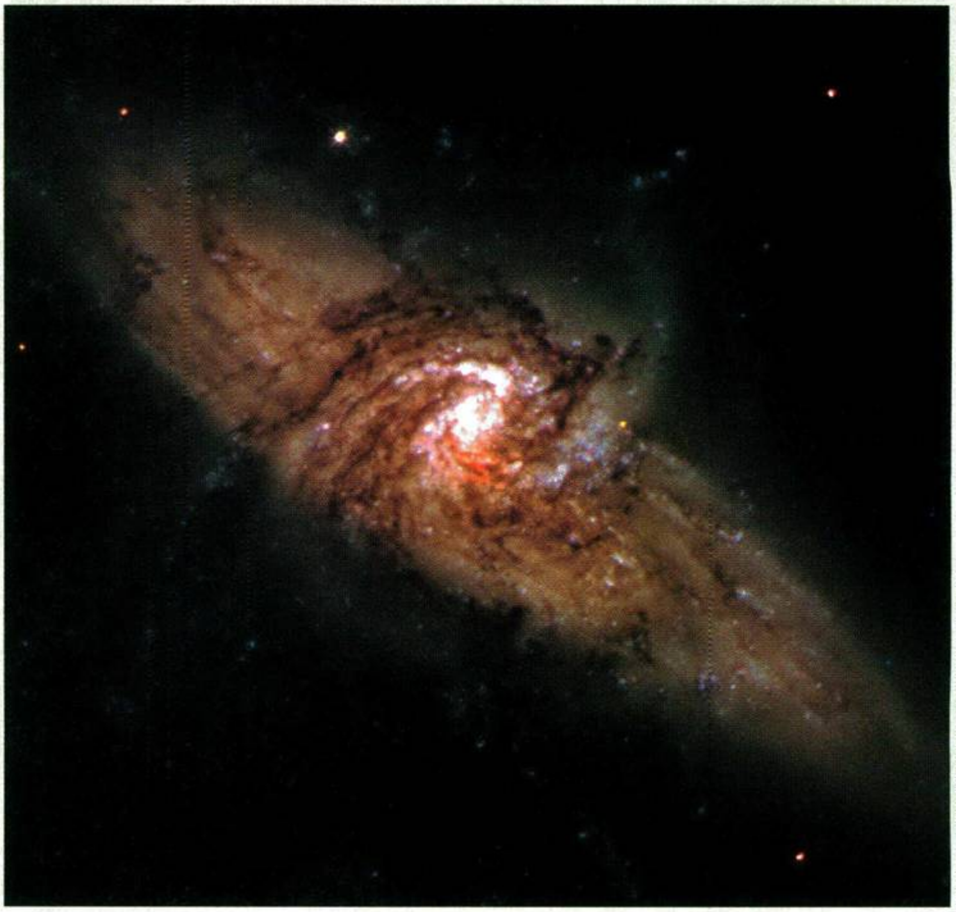
The brown dwarfs turned up in images taken by the Sloan Digital Sky Survey, a five-year project to image one-fourth of the sky. Spectra taken at the United Kingdom Infrared Telescope (UKIRT) in Hawaii by UKIRT astronomer Sandy Leggett, Thomas R. Geballe of the Gemini Observatory, and Gillian Knapp and Alexander McDaniel of Princeton University clearly show that these brown dwarfs have properties that fall between the two extremes.

The three brown dwarfs have spectral lines of both methane and carbon monoxide. Hot brown dwarfs show abundant carbon monoxide and no methane, while the situation is reversed in cool brown dwarfs. "They also show strong water lines and lines for cesium and potassium," says Leggett.

"This is an important discovery from the standpoint of classifying these objects," says Caltech brown dwarf hunter Adam Burgasser. Brown dwarf researchers have been calling the hot brown dwarfs "L dwarfs" and the cool brown dwarfs "T dwarfs." The new objects will probably be classified at the upper end of the T sequence. "Now we have essentially a continuous sequence from the hottest O stars to the very coolest T-type brown dwarfs," adds Burgasser.

But as Burgasser's Caltech colleague Davy Kirkpatrick points out, "There's another huge temperature gap in the T sequence between the coolest known brown dwarf, Gliese 570D, and Jupiter. We have a lot of work ahead, but this field is making giant leaps forward." — Robert Naeye

**HUBBLE SPACE TELESCOPE**



NASA and The Hubble Heritage Team (STScI/AURA)

**THIS GALACTIC SILHOUETTE lies about 140 million light-years from Earth in Hydra. Although the two spiral galaxies, known collectively as NGC 3314, might seem to be interacting, they simply lie along the same line of sight. Astronomers William Keel and Ray White of the University of Alabama used this chance alignment to study the gas and dust in the spiral arms of the foreground galaxy. The hot, blue stars that form the central pinwheel pattern were born recently from interstellar gas and dust. In many galaxies, interstellar dust appears only in proximity to such stars. In this one, however, several dark dust lanes seem to stand alone. The outer spiral arms of the nearer galaxy appear to change from dark to light as they are projected against the background galaxy and deep space. The reddish patch near center is the bright nucleus of the background galaxy, reddened as its light passes through material in the foreground one.**

*SPACE SCIENCE*

# Dusting for Stars

▶ Catch a falling star . . . or at least some stardust.

The Jet Propulsion Laboratory's Stardust spacecraft, launched February 7, 1999, snagged stardust for ten weeks this past spring. Stardust will now store its high-tech "catcher's mitt" for two years, when it will deploy once again to collect more particles of interstellar dust.

Then in late December 2003, the opposite side of the collector deploys to catch dust from Comet Wild 2, which the spacecraft will fly past on January 2, 2004. Two years after that, Stardust returns to Earth with its precious cargo, parachuting softly to the ground in Utah. These will be the first solar system samples returned to Earth since the moon landings of the early 1970s.

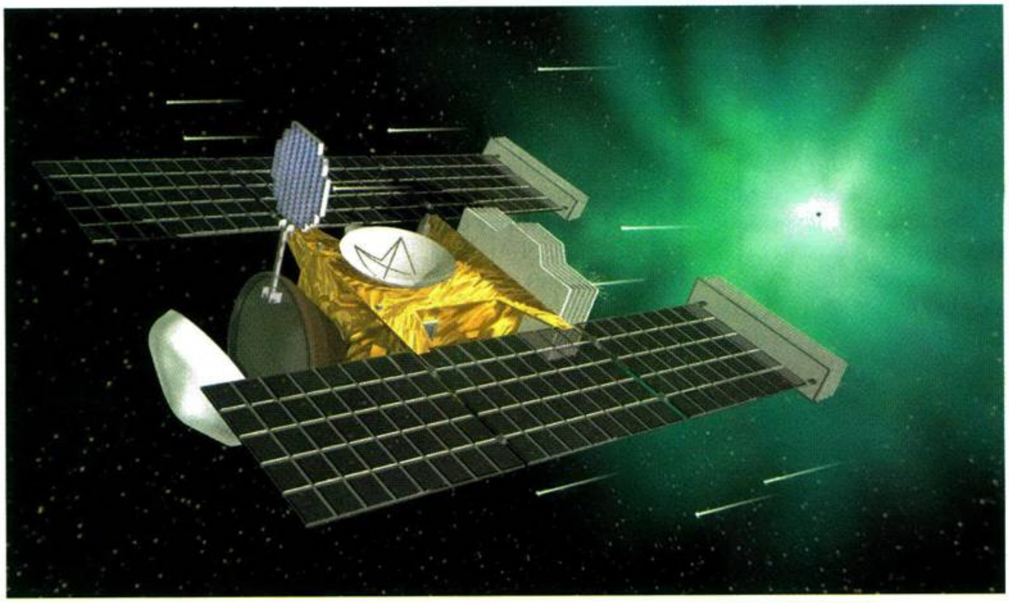
The dust collected recently belongs to a stream of particles that flows through the solar system. "These particles contain the heavy chemical elements that originated in the stars," says the Principal Investigator for Stardust, Donald Brownlee of the University of Washington in Seattle. "Since nearly every atom heavier than hydrogen in our bodies came from the inside of stars, by studying these interstellar dust particles we can learn about our cosmic roots."

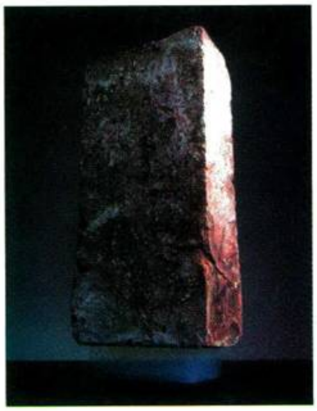
Stardust's special collecting device contains aerogel, a porous silicon-based structure capable of stopping microscopic cosmic debris without damaging the dust. Despite its fragile, lighter-than-air appearance, aerogel captures, slows, and stops space dust within a fraction of an inch. Snared particles bore carrot-shaped tunnels in the aerogel.

"It's the first time anyone has attempted to catch anything like this and bring it home," says Stardust Project Manager Kenneth Atkins of JPL. "These tiny particles zip by at 20 to 25 kilometers per second (about 45,000 to 56,000 mph) relative to the spacecraft."

The opposite side of the dust collector is reserved specifically for Comet Wild 2. Astronomers targeted this comet because of its pristine nature. Wild 2 orbited undisturbed beyond Jupiter until 1974, when a close encounter with the giant planet changed its course and brought it into the inner solar system. It now comes about as close to the sun as Mars. Stardust will encounter the comet on just its fifth trip into the sun's vicinity, so it will have changed little since the formation of the solar system.

The total amount of interstellar and comet dust collected and returned to Earth will weigh less than one-thousandth of an ounce. "I'm thrilled at the thought of being able to look at and study these particles firsthand," says Brownlee. — Carol Ryback





**Above: The Stardust spacecraft will fly past Comet Wild 2 in January 2004, collecting samples of dust and bringing them to Earth. This spring Stardust captured some interstellar dust in its high-tech catcher's mitt.** NASA/JPL **Left: A piece of aerogel weighing less than one-tenth of an ounce (2 grams) supports a 5.5-pound (2.5 kg) brick. Aerogel — often called blue smoke because of its color and transparent nature — is 99.8 percent air.** NASA/JPL

*COSMIC SCALE*

# Finding the Lost Hydrogen

▶ Until early 2000, astronomers were in a quandary. Like an accountant who can't locate half his company's assets, they couldn't find 50 to 80 percent of the normal matter predicted by the big bang theory. But new observations from Hubble's Space Telescope Imaging Spectrograph (STIS) may help alleviate this situation.

Todd Tripp and Edward Jenkins of Princeton University, along with Blair Savage of the University of Wisconsin, used a quasar billions of light-years away like a cosmic flashlight. With STIS they looked for material absorbing some of the quasar's ultraviolet light en route to Earth. The team found four pairs of dark lines in the quasar's spectrum that come from highly ionized oxygen. In other words, four intergalactic clouds of oxygen were absorbing the quasar's light.

Ionized oxygen is key because it serves as a tracer for hydrogen, which is by far the most common element in the universe. Just as you can be sure to find lint wherever you find a pile of clothes, astronomers can be sure hydrogen exists wherever they find oxygen. The hydrogen itself is invisible because the temperature of the intergalactic clouds exceeds 100,000 kelvins. The heat strips electrons from hydrogen atoms and ionized hydrogen can't absorb light.

Based on the amount of observed oxygen, Tripp, Jenkins, and Savage argue that much of the universe's missing normal matter exists as hot, diffuse gas between galaxies. This conclusion agrees nicely with supercomputer models that simulate the evolution of the universe. "This is a promising initial result that indicates that the supercomputer models of cosmological-structure evolution are on the right track. But many more observations are needed," says Tripp.

Other astronomers note that the team found only eight spectral lines in the direction of just one quasar. "Their data are good, but they probably should have waited another year to get more Hubble data. They might be right, but they don't have enough ammunition to make such an emphatic conclusion yet," says Chris Impey of the University of Arizona. Impey notes that a new instrument to be installed on Hubble in 2003, the Cosmic Origins Spectrograph, will improve on STIS's sensitivity for this kind of study tenfold.

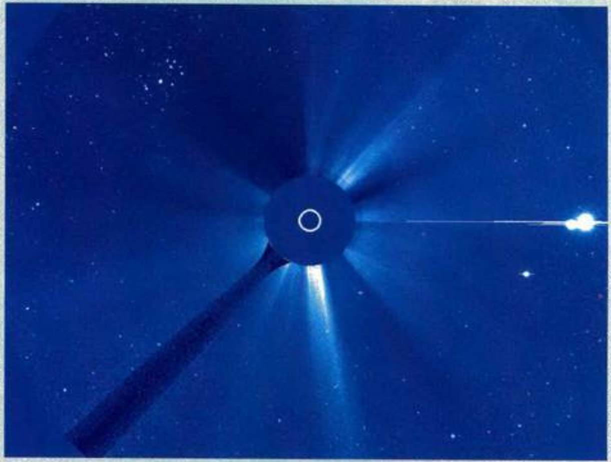
Tripp agrees more work has to be done. "We are very excited about this first result, but there are substantial uncertainties in the current measurements. There may be a lot more of this stuff that we can't see by our current technique. Our sample is indeed small. We also have to make an assumption about the total oxygen-to-hydrogen ratio."

Even if Tripp, Jenkins, and Savage turn out to be right, they haven't resolved the bigger dark-matter mystery. Astronomers have known for decades that most of the mass of the universe is in some form other than the "normal" matter that makes up protons, neutrons, and electrons. "Our result has no impact on the issue of the dark matter," says Tripp. — R. N.

**Four intergalactic clouds lie between Earth and this quasar.**

WIYN Telescope/NOAO

## PLANET ALIGNMENT



SOHO/LASCO (ESA and NASA)

**THE GRAND PLANET ALIGNMENT of May 2000 offered little for backyard observers because the planets all lined up with the sun. But for astronomers working with the Solar and Heliospheric Observatory (SOHO), the alignment was right up their alley. This SOHO image shows the sun and its surroundings on May 17, when Jupiter and Venus lay just 1/100° from each other. The two brightest planets appear to be touching on the right side of the image with dimmer Saturn located a little below and to their left. (The horizontal lines are not planetary rings but "pixel bleeding" from the over-exposure.) The LASCO C3 instrument on SOHO uses a mask to block the sun (the white circle at the image's center indicates its size) and reveal its corona. The instrument's 15° field of view easily captured the three planets and the Pleiades star cluster at upper left.**

*STELLAR ASTRONOMY*

# Violent End for Sunlike Stars

▶ Astronomers have long wondered about a prominent emission feature seen in the spectra of a few stars. Located in the infrared at a wavelength of 20.1 micrometers, the feature was first observed in 1983 by the Infrared Astronomical Satellite (IRAS). The Infrared Space Observatory (ISO), a 24-inch (60 cm) infrared telescope launched by the European Space Agency in November 1995, showed this feature in great detail in about 15 stars. However, what compound produced this emission remained a mystery until a chance meeting earlier this year.

That's when one of the ISO researchers, Xander Tielens of the University of Groningen in the Netherlands, was offered a tour of the FOM Institute for Plasma Physics in Rijnhuizen, near Utrecht. He was there to discuss laboratory investigations of polycyclic aromatic hydrocarbons, another compound often

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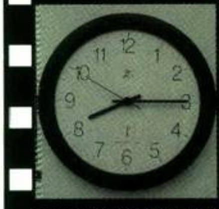

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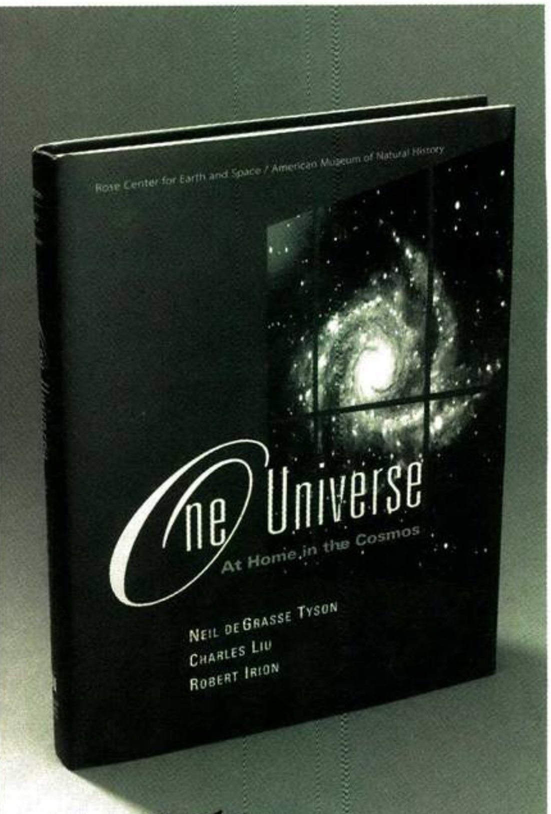


*The vastness and the mystery of the universe brought down to Earth.*

found in clouds around stars. It just happened that some researchers at the Institute studied the spectra of titanium carbide nanocrystals. "They showed me this poster and I thought, 'This is interesting, they also have a 20-micron feature,'" says Tielens. "Back in Groningen I realized that there was more to it than coincidence," he adds.

He faxed the ISO spectrum to the FOM researchers, and when they superimposed it on their laboratory spectrum, they found it matched perfectly. "It's the best fit I ever have seen. . . . It was sheer serendipity," says Rens Waters of the University of Amsterdam and one of the authors of the paper that appeared in the April 15, 2000, issue of *Science*.

The number of stars displaying this infrared feature is small because titanium carbide nanocrystals are produced only during a very short period during the death throes of a star — about 1,000 years while emerging from the red giant phase to form a planetary nebula, explains Waters. These stars contain more carbon than oxygen in their outer layers.

This discovery also shows that these stars die more violently than was previously thought. The Dutch astronomers were able to determine the rate at which the dying star ejects mass into space by calculating how much titanium carbide has to be present to form the infrared spectral feature. The chance that two titanium carbide molecules meet to form a nanocrystal is very small, therefore the density of the outflowing gas has to be high, explains Waters. "The density is a measure of the rate of mass loss in these stars, and we were able to calculate that these stars eject the equivalent of half the mass of the sun in a few hundred years," says Waters. "This is ten times more than what we thought up to now."

Harald Mutschke of Jena University in Germany agrees that the discovery of titanium carbide in space has solved the long-standing mystery of emission in the 20-micrometer region: "There have been two or three proposals for the kind of material that possibly would produce such a band, but they turned out to be wrong." Titanium carbide nanocrystals are also found in certain meteorites, and some astronomers had a hunch that this compound could form in stars, he adds. "Now we really have proof that titanium carbide occurs there."

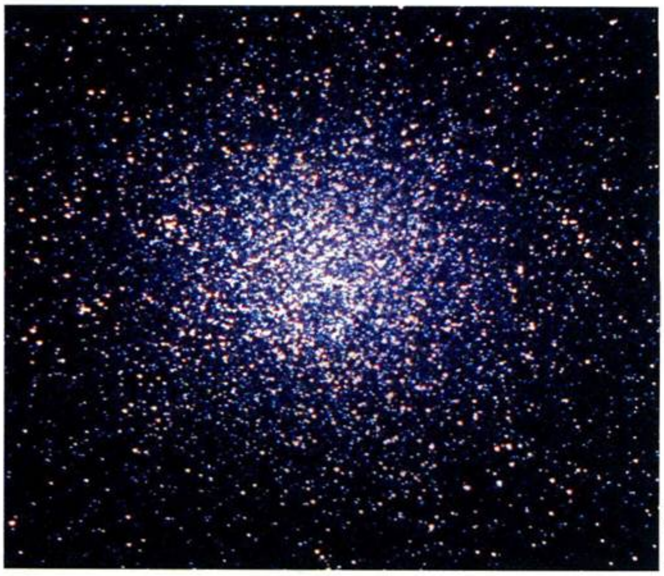
— Alexander Hellemans

*MILKY WAY EVOLUTION*

## Capturing a Globular Cluster

▶ Many astronomy enthusiasts have the impression that globular clusters are boring. Sure, they're big and often bright, but in a telescope they possess a numbing sameness. Even astronomers get caught in this mindset because globulars are old and essentially unchanging.

But appearances can be deceiving. A recent study by a team of astronomers led by Young-Wook Lee of the Center for Space Astrophysics at Yonsei University in Korea shows that not all globulars fit this pattern.


James Foster

**The brightest globular cluster in the sky, Omega Centauri, apparently formed in a dwarf galaxy that later merged with the Milky Way.**

The researchers found that Omega Centauri (NGC 5139) — the most massive globular in the Milky Way Galaxy — has experienced several bursts of star formation and may once have belonged to a dwarf galaxy that merged with our own.

Using the 0.9-meter telescope at Cerro-Tololo Interamerican Observatory in Chile, the team observed more than 130,000 stars in Omega's direction. To their surprise, they found that the red giant stars in the cluster showed marked differences.

A star spends roughly 90 percent of its life calmly fusing hydrogen into helium in its core. Once the hydrogen fuel gets exhausted, however, the star's internal structure changes. The star swells to 10 to 100 times its former size and its surface grows cooler and redder — a red giant is born. In a cluster the size of Omega Centauri, literally hundreds of stars are evolving to become red giants.

What Lee's team found is that these evolving stars fall into several groups with slightly different colors and brightnesses. This can happen only if the stars in each group contain a different proportion of elements heavier than helium. The amount of these elements rises with the cluster's age as stars eject their outer layers, so this implies that the groups formed at different times. In Omega's case, the youngest were born about 2 billion years after the oldest.

The researchers argue that if Omega began life near the dense inner regions of the Milky Way, any gas in the cluster would have been stripped and no new stars could have formed. They conclude that Omega most likely formed in a gas-rich dwarf galaxy that merged with ours some 2 billion years after its first generation of stars was born.

If so, Omega bears a striking resemblance to the Sagittarius dwarf galaxy — a system currently merging with the Milky Way that has three distinct groups of red giant stars that formed over a period of 3 billion years.

— Richard Talcott

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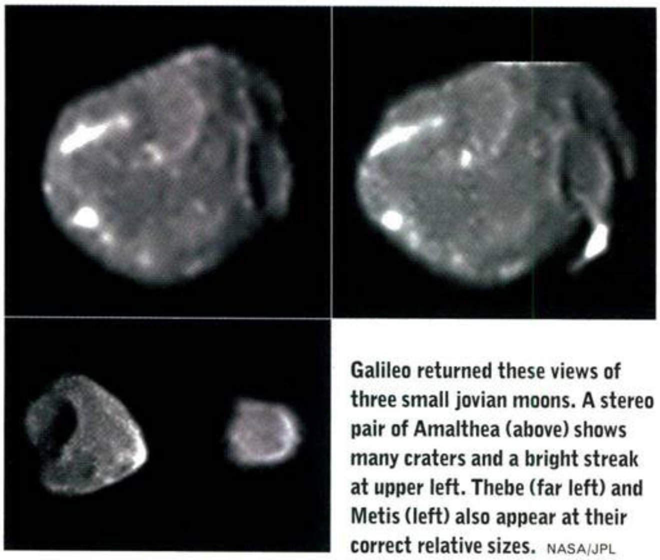


Galileo returned these views of three small jovian moons. A stereo pair of Amalthea (above) shows many craters and a bright streak at upper left. Thebe (far left) and Metis (left) also appear at their correct relative sizes. NASA/JPL

*GALILEO MISSION*

# Jupiter's Tiny Attendants

▶ Everyone knows Jupiter's four big Galilean moons: Io, Europa, Ganymede, and Callisto. High-resolution images from the Voyager and Galileo spacecraft turned these objects into fascinating worlds in their own right, with mountains, craters, volcanos, and under-ice oceans.

Yet Jupiter has 12 smaller moons that have received none of the fanfare of their bigger siblings. Now Galileo has started to change that. New images of the inner moons Amalthea, Metis, and Thebe show details as small as a mile or two across, sharp enough to reveal craters, bright patches, and an odd linear streak.

Until last summer, Galileo hadn't ventured closer to Jupiter than the orbit of Europa — some 420,000 miles away. (Mission planners wanted to steer clear of Jupiter's intense radiation until most of the mission's objectives had been met.) Metis, Amalthea, and Thebe lie only 80,000, 112,000, and 138,000 miles from Jupiter's center, respectively.

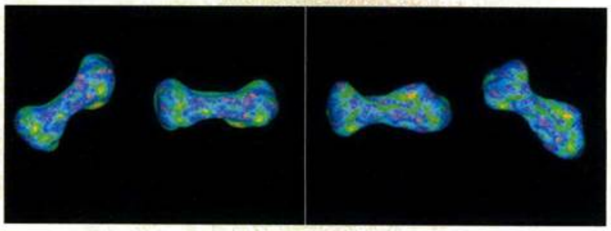
Since last summer, the spacecraft has made three close approaches to the innermost large moon, Io. It was during these potentially kamikaze excursions that Galileo targeted the three inner moons.

Although the 25-mile-wide Metis shows only some vague markings, the other two moons explode with detail. A crater 25 miles across dominates Thebe, which itself is only about 60 miles across.

At 150 miles in diameter, Amalthea ranks as the fifth largest of Jupiter's moons. It has a few large craters, but according to Damon Simonelli of Cornell University, who led the team that enhanced the images, its most intriguing feature is a 30-mile-long streak of bright material. Named Ida, the feature appeared as a bright spot in previous images taken at different viewing angles. He suspects that the streak could be material ejected from a nearby impact crater or the crest of a ridge. — R. T.

## Kleopatra Revealed As Cosmic Dog Bone

Radar observations made with the Arecibo radio telescope in Puerto Rico show the distant asteroid 216 Kleopatra to be shaped like a dog bone. Steven Ostro of the Jet Propulsion Laboratory, who led the team that made this first-ever radar study of an asteroid beyond Mars, says "Kleopatra has the most unusual shape we've seen in the solar system. It could be the remnant of an incredibly violent collision between two asteroids that did not completely shatter and disperse all the fragments." The team reported on their observations and computer modeling in the May 5, 2000, issue of *Science*.



Steven Ostro (JPL), et al.

Radar reveals Kleopatra as man's best friend's friend.

## Seven New Planets and Brown Dwarfs

European astronomers have discovered seven new substellar objects in orbit around nearby stars. The team, led by Michel Mayor of the Geneva Observatory in Switzerland, used a 1.2-meter telescope at the European Southern Observatory's La Silla facility to detect the subtle changes in velocity caused by the objects pulling on their parent stars. One of the new planets has a minimum mass 80 percent that of Saturn, making it just the third extrasolar planet that could be smaller than Saturn. Two of the other planets appear slightly heavier than Saturn. One of these — circling the star HD 83443 — has the shortest period (2.99 days) of any planet yet seen. The final two planets are between two and three times the mass of Jupiter, while the brown dwarfs are each about 15 times Jupiter's mass. "These discoveries enlarge our still preliminary knowledge of extrasolar planetary systems as well as the transition between planets and brown dwarfs," says Mayor.

## Albert Returns from the Dead

Astronomers have recovered the last "lost" minor planet, an object that hadn't been seen in 89 years. Asteroid 719 Albert was discovered on October 3, 1911, by Johann Palisa at the Imperial Observatory in Vienna, Austria. He saw it again the next night, as did another astronomer at Copenhagen Observatory. And that was the last time it was seen until May 1, 2000. That's when Jeff Larsen spotted it during an observing run with the University of Arizona's 0.9-meter Spacewatch Telescope. Within a week the object had been observed several more times and had its orbit calculated, which proved it to be the long-lost Albert.

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RICHARD WOLFSON, Ph.D., is a professor of physics at Middlebury College, where he has also held the George Adams Ellis Professorship of the Liberal Arts. A versatile physicist and science educator, Wolfson has published in such diverse fields as medical physics, experimental plasma physics, electronic circuit design, solar energy engineering, and theoretical astrophysics.

A legend among students for more than two decades at his own highly regarded campus, where his innovative and interesting courses are perennially filled, he is equally at home before a nontechnical audience. And his work outside the university arena, whether writing an article for *Scientific American* or creating a book-length explanation of *Nuclear Choices: A Citizen's Guide to Nuclear Technology*, has given Americans a new understanding of science and its impact on our lives in an age of extraordinary scientific discovery.

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Telescopes for the 21st Century

# Europe's Science Machine

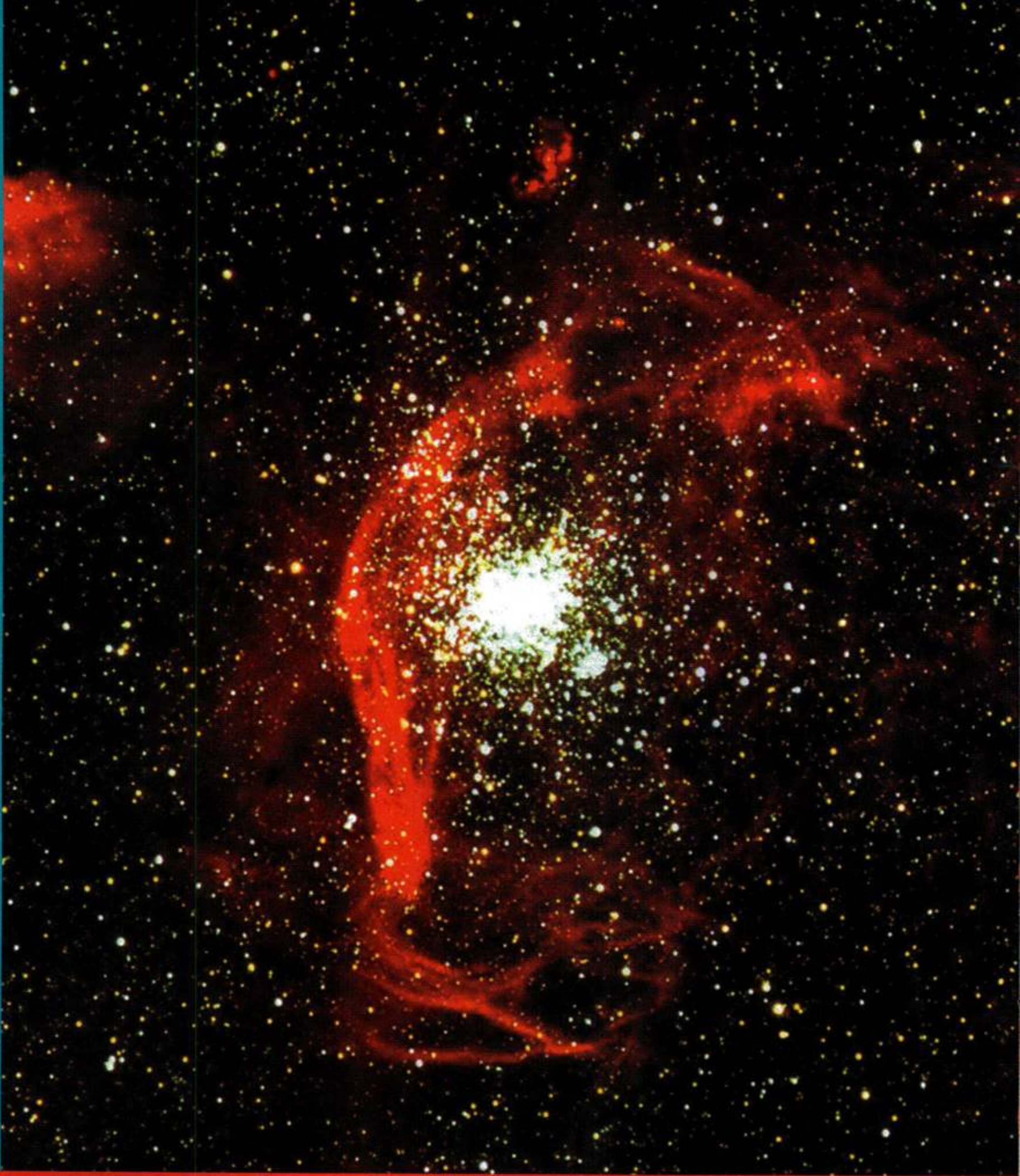
## *The Very Large Telescope will revolutionize astronomy in the 21st century.*

**by Govert Schilling**

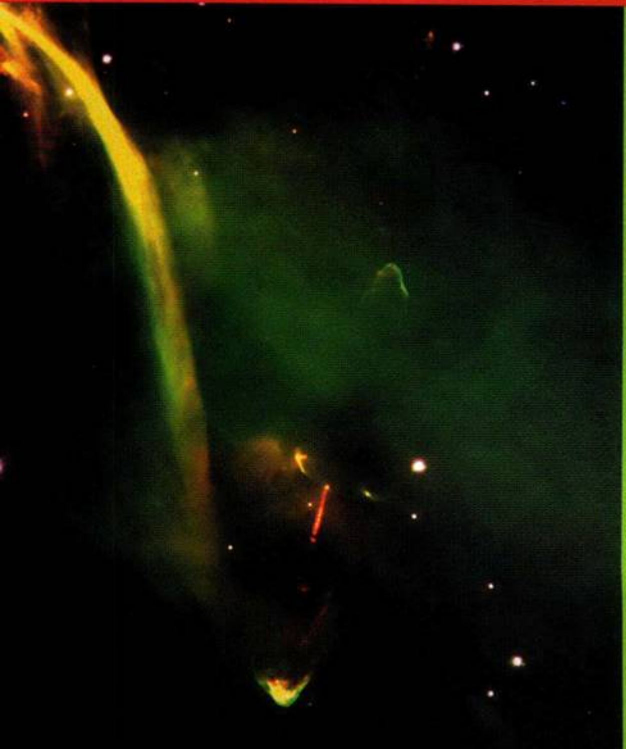
On a desolate mountaintop in northern Chile, European astronomers are gearing up to complete the world's most powerful optical observatory. Called the Very Large Telescope (VLT), it will be an astronomical workhorse for decades to come, providing scientists with record-breaking light-gathering power and a vision much sharper than the Hubble Space Telescope's.

The Very Large Telescope consists of four identical 8.2-meter telescopes perched atop 8,635-foot-high (2,632-meter) Cerro Paranal (see "King of the Mountain," March 1999). This summer, the fourth and final telescope will see first light, and by mid-2001 the quartet will be conducting routine science observations.

**New stars are forming in the Chamaeleon 1 complex.** All photos: European Southern Observatory

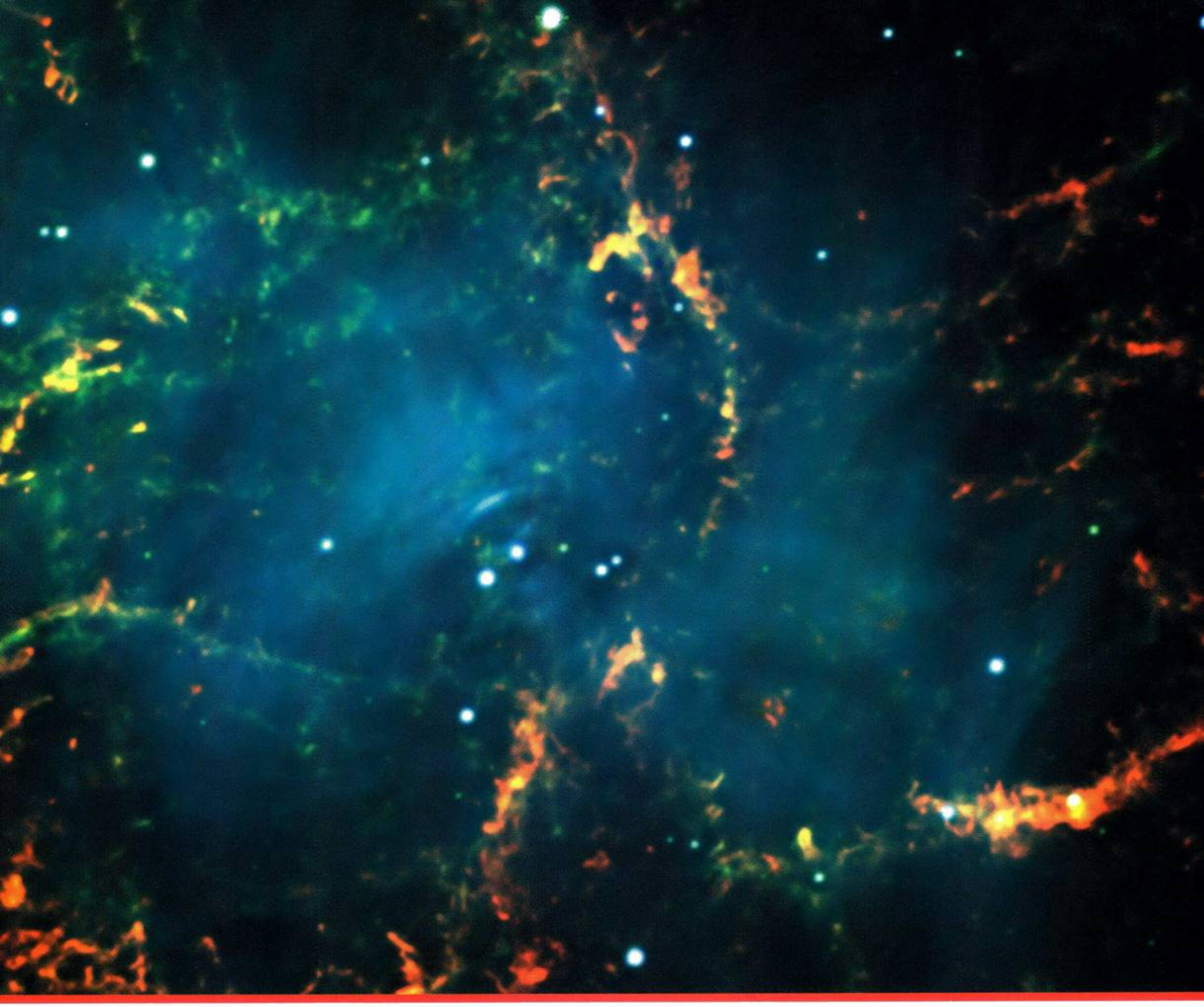


**Right: The young star cluster NGC 1850 contains hundreds of massive stars. About 1,000 stars in the cluster have already gone supernova, perhaps triggering the birth of stars in the smaller cluster at the right. Far right: The central region of the Crab Nebula (M1) is a seething realm of ionized gas. Bottom: A jet of high-speed gas (red line) shoots away from a protostar. When the jet rams into the surrounding gas, it generates a shock front (HH-34) seen as the arrow-shaped green region at the bottom. The "waterfall" at the upper left remains unexplained.**



Built by the European Southern Observatory (ESO), an eight-member-state organization, the $500-million VLT got the go-ahead in December 1987. "The VLT is the only major telescope project that's being built on schedule and within budget," says former ESO director-general Riccardo Giacconi. Results obtained with just the first telescope have already made headlines: the first polarization measurement of a gamma-ray burst, the detection of dust-enshrouded galaxies in the early universe, and the birth of large numbers of low-mass stars in a galactic star-forming region.

Cerro Paranal, 80 miles (130 kilometers) south of the Chilean harbor town of Antofagasta, lies in the Atacama Desert, one of the driest regions on Earth. The observatory site still bustles with construction activity. Apart from the four main telescopes, ESO is planning at least three 1.8-meter auxiliary telescopes to increase the interferometric capabilities of the VLT. In interferometric mode, signals from two or more telescopes are combined to yield the same resolution as a single 130-meter mirror.



The four VLT telescopes are named Antu, Kueyen, Melipal, and Yepun, the names of the sun, the moon, the Southern Cross, and Sirius, respectively, in the local Mapudungo language. A Chilean schoolgirl proposed the names as part of a contest sponsored by ESO. Antu was the first to be completed. First light was achieved in the spring of 1998, and astronomers have used the telescope since April 1999. Equipped with sensitive infrared and optical cameras and spectrographs, Antu has studied comets, protoplanetary disks, planetary nebulae, supernova remnants, and distant radio galaxies.

The second telescope, Kueyen, saw first light in March 1999. It was handed over to astronomers last April after a year-long commissioning phase. Kueyen's principal detectors are two giant spectrographs. "It is expected to produce half a million stellar spectra in the next 10 years," says astrophysicist Rolf Kudritzki, the director of the Munich University Observatory in Germany. Kueyen will also be able to take visible light images.

Melipal, the third VLT telescope, saw first light in January and is currently being tested. Its first science instrument is primarily designed for spectroscopic studies of extremely distant galaxies in the early universe. The telescope will be equipped with an adaptive optics system to compensate for atmospheric turbulence. Of the four telescopes, Melipal will be the best suited for cosmology.

Yepun is expected to see first light in July 2000. The telescope's mechanical structure was completed in May 1999 and its 8.2-meter primary mirror arrived at Paranal in April 2000. It's the best optical mirror in the world, with a surface accuracy of 8.5 nanometers (a nanometer is a millionth of a millimeter). If the United States were as flat as Yepun's mirror, its tallest peak would be less than an inch high. Such exquisite optics may be decisive in studies of extrasolar planets, although the telescope might not be able to directly image planets. Nevertheless, the study of the birth and structure of other planetary systems will be a major occupation of the VLT.

## VLT WEBSITE

**To view more VLT images, go to:**

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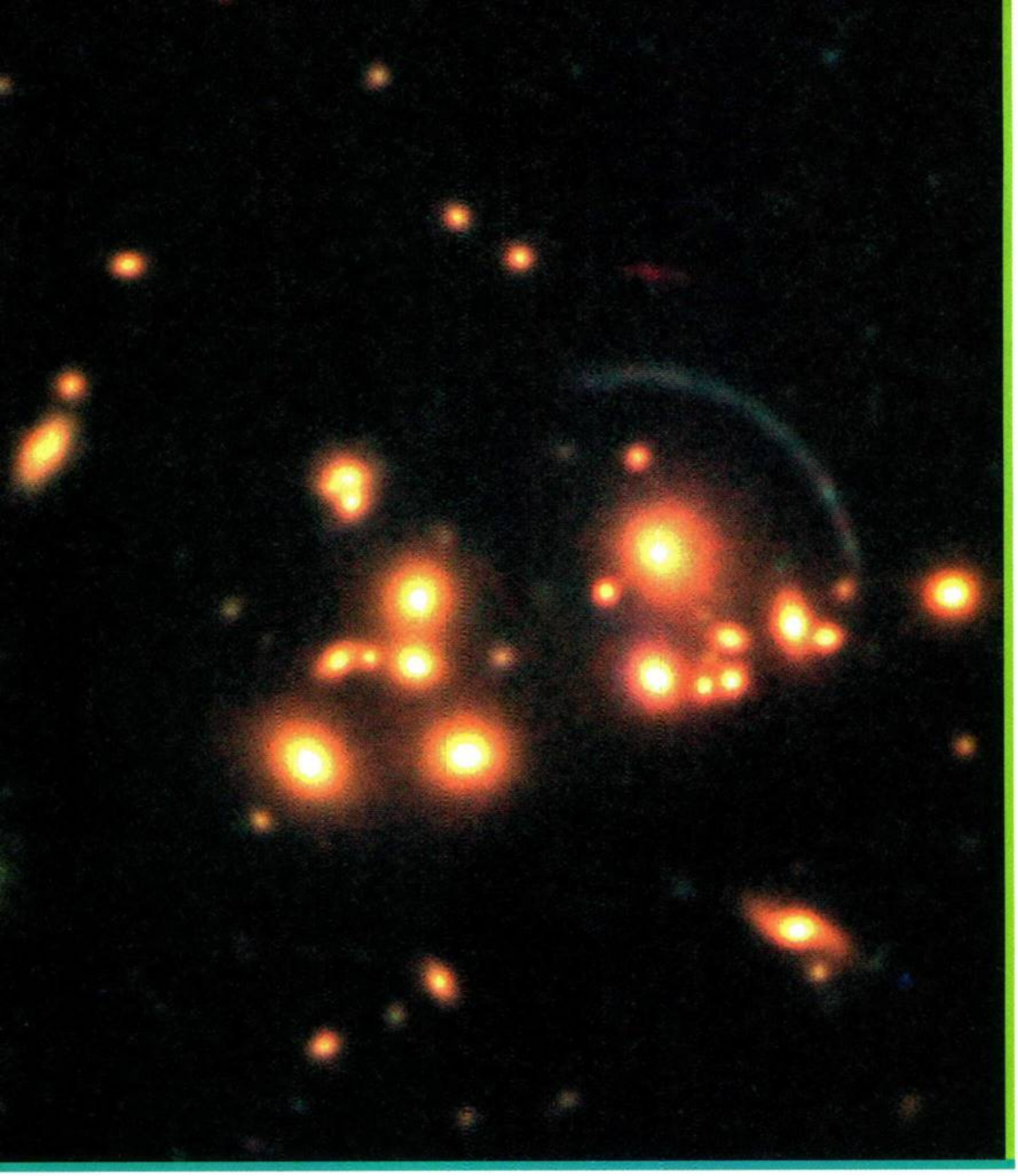


**Far left: Unlike previous ground-based telescopes, an individual VLT scope can image both the bright and dim stars in the star cluster NGC 3603. The observations prove that both high- and low-mass stars are born together in this group. Near left: The mass of galaxy cluster CL2244-02 is so large that it gravitationally lenses the light of more distant galaxies into thin arcs. Bottom left: The four telescopes of the VLT stand tall before a Chilean Andes sunset. From left to right in the background are Antu, Kueyen, and Melipal, all of which are operational. The telescope in front, Yepun, is still under construction.**

After completion of Yepun, work will commence on the three auxiliary telescopes, and in a few years' time, the full interferometric capabilities of the VLT should be available. The auxiliary telescopes can be moved around to dramatically increase resolution, just like the 27 individual dishes of the Very Large Array radio telescope in New Mexico.

When running as an interferometer, the VLT will have the light-gathering power of a 16-meter telescope and the razor-sharp vision of a 130-meter mirror. Although the interferometric field of view is very small, the VLT Interferometer will provide scientists with extremely detailed views of a wide variety of objects, from asteroids in our solar system to dust disks and planets orbiting other stars to the immediate surroundings of supermassive black holes in distant galaxies.

Optical interferometry, however, will not be used continuously. For a significant fraction of the time, Antu, Kueyen, Melipal, and Yepun will each run their own observing programs.

Running a complex facility such as the Very Large Telescope is no minor task. The four telescopes and their spate of instruments will collect an enormous flood of data, all of which have to be calibrated, analyzed, and archived. To this end, ESO computer scientists have developed the VLT Data Flow System, which eventually will produce more than 20 gigabytes of data each night — enough to fill 30 CD-ROMs.

The Very Large Telescope, which Giacconi calls a "science machine," is an astronomical success story. The results obtained so far, some of which are being presented on these pages, are whetting the appetite for things to come. Stay tuned, because you ain't seen nothing yet. ◼

---

*Dutch writer Govert Schilling is the author of more than 20 astronomy books, including an upcoming book about gamma-ray bursts. He writes frequently for* Astronomy. *His most recent article was "Giant Eyes on the Sky," in the December 1999 issue.*

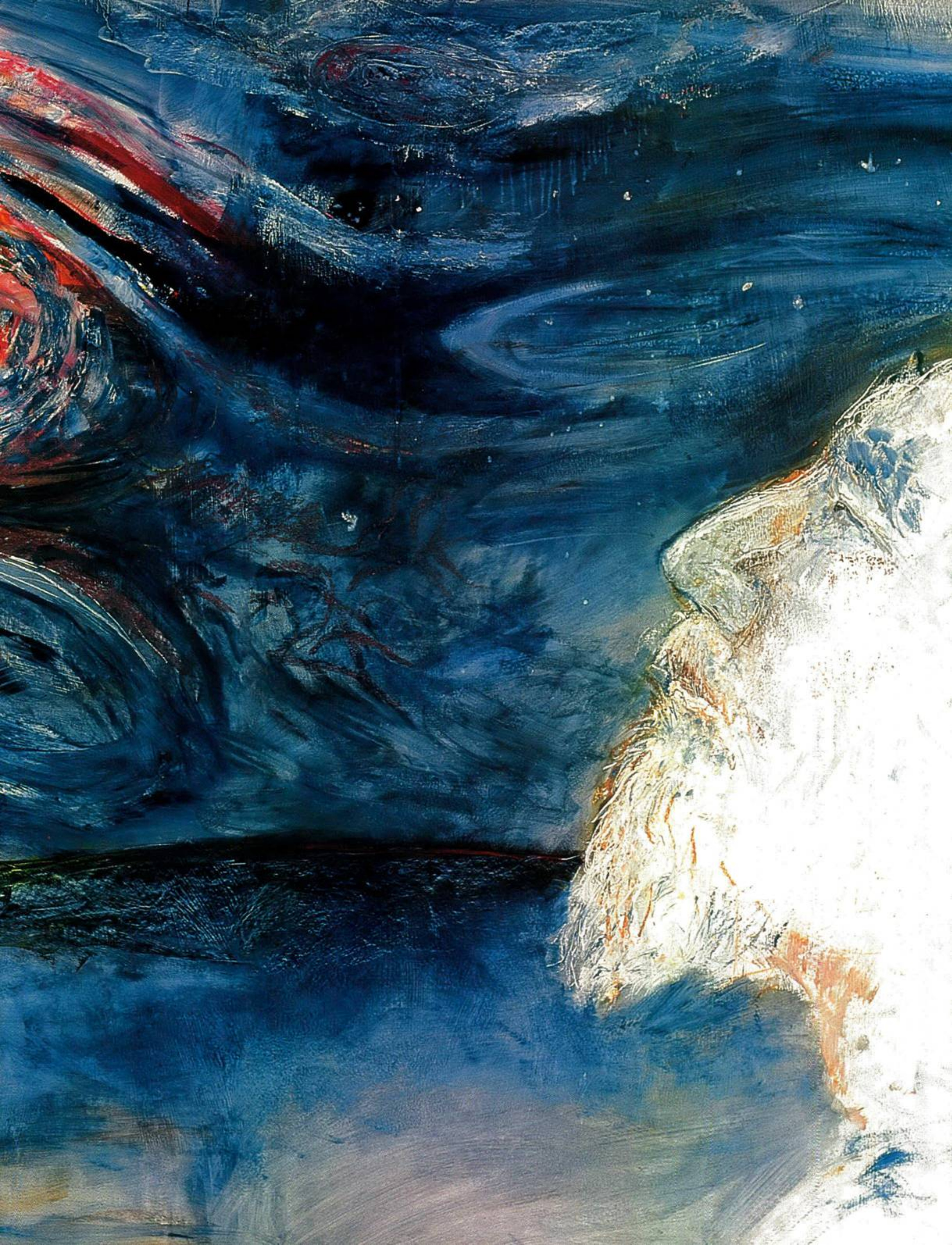
# *Rounding the* EARTH

Centuries before Columbus, ancient astronomers perceived graceful curvatures in their universe.

by James Trefil

Everyone who lived before Christopher Columbus thought Earth was flat, right? Actually, Greek scientists knew Earth was a sphere thousands of years before Columbus first sailed the Atlantic. That knowledge was incorporated into the book that served as the standard astronomy text in medieval universities. Columbus didn't have to convince educated men and women that he could reach the East by sailing west. His task was more practical. He had to convince them that Earth's circumference was small enough to allow him to reach China before his ships would run out of food and drinking water.

Marie Larson



Universal belief in a flat Earth in Columbus's day is a myth — one example of a modern tendency to assume those who came before us were less able to cope with the universe. The cumulative nature of science is partly to blame. Each discovery raises new questions, which scientists answer later. Modern college students know more about physics than did Isaac Newton. Of course, that doesn't make the students geniuses. Indeed, the more I discover what ancient scientists did with primitive instruments, the more impressed I become.

None of these observations requires sophisticated equipment — just an ability to put together everyday observations.

## *Ptolemy's Arguments*

Take the shape of Earth. Second-century Egyptian astronomer Claudius Ptolemy (evidence suggests he died in A.D. 141 or 151 at age 78) compiled the work of astronomers dating back 400 years. He called the book *The Mathematical Composition*, but to later generations it became known as the *Almagest*, a word put together by Arab astronomers from their article *Al* and the Greek *megiste*, or great. This book was the encyclopedia of astronomy until the Renaissance — a shelf life that modern publishers can only dream about. (As a geographer Ptolemy also produced a collection of maps in *Geography*, which Columbus read and concluded that it must be possible to reach India by sailing west.)

A few pages into Book I of the *Almagest* we find a section titled "That Also Earth, Taken as a Whole, Is Sensibly Spherical." In a single densely worded page, Ptolemy gives a variety of arguments to support the proposition that Earth is round, including these:

- The sun, moon, and stars do not rise at the same time everywhere on Earth.
- Events such as lunar eclipses that take place at a specific time as seen from any vantage point occur at earlier local time in the west than in the east. If Earth were flat, the event would occur at the same local time at two distant locations.
- The difference in local time between these events is proportional to the distance between them, as you would expect for points located on the surface of a sphere.
- As an observer travels north, southern constellations disappear from view and northern constellations move higher in the sky.
- When a ship sails toward shore, a mountain may appear to rise from the sea, as would be expected if its lower parts were hidden by Earth's curvature.

None of these observations requires sophisticated equipment — just an ability to put together everyday observations. Of course, this kind of reliance on common sense and everyday observation can get you into trouble. For example, the same sorts of arguments a few pages later in Ptolemy's book bolster the notion that our planet is the stationary center of the universe. In this section, Ptolemy marshals the best science of his day to support this conclusion.

Aristotle had taught (wrongly) that heavy objects fall toward the center of the universe faster than light ones. Ptolemy argued that if Earth were not at the center of the universe, it would be falling toward the center. Furthermore, because of its great mass, Earth would fall faster than anything would on it, leaving human beings, dogs, and the pyramids floating in space.

I don't mention these points as criticism of Ptolemy. After all, many centuries would pass before the genius of scientists such as Galileo, Isaac Newton, and Robert Hooke worked out the subtle connections between gravity and centrifugal force that, in the end, answered Ptolemy's objections.

## *Spherical Roots*

Actually, Ptolemy wasn't the first to argue that Earth was round. The first were followers of the mathematician Pythagoras around 500 B.C. They appear to have argued that Earth was spherical and rotated on its axis, although they did not apply Ptolemy's rigor to the subject. Furthermore, about 350 years before Ptolemy set down his ideas, a fellow Alexandrian scientist trained in the Greek tradition — Eratosthenes — not only accepted the spherical shape of Earth, but also devised a way to measure its circumference.

Eratosthenes was born in the town of Syene (now Aswan, Egypt), which is near the Tropic of Cancer. To get Earth's radius, Eratosthenes dug a deep well and made two measurements. At noon on the summer solstice, when the sun was directly above Syene, sunlight would illuminate the bottom of a well there. Also at noon on the same day, he measured the length of a shadow cast by a pointer fixed in a hemispherical bowl in Alexandria. Knowing that the direction of the sun's rays are the same at Syene and Alexandria, and noting that the length of the shadow in Alexandria stretched over $\frac{1}{25}$ of the hemisphere (and hence over $\frac{1}{50}$ of a sphere), he concluded that the distance between the two towns was $\frac{1}{50}$ of the circumference of Earth.

So far, so good. Modern astronomers confirm that the angle measurement is about right. To convert it to an estimate of Earth's radius, however, Eratosthenes had to know the distance between Syene and Alexandria. He did not have the kind of trigonometry that would make a modern survey possible, so he had to rely on a less accurate estimate. The rulers of Alexandria employed a core of "pacers" — men who counted their steps as they trekked from town to town. From their reports, Eratosthenes concluded that the two towns were separated by 5,000 *stades*, a Greek measurement from which we derive stadium. (One stade is about 600 feet.) Eratosthenes reported Earth's circumference to be 252,000 stades (he apparently threw in the extra 2,000 stades so that the final number would be divisible by 60). A judgment of the accuracy of this figure depends on which of the ancient stades Eratosthenes actually used — a subject of scholarly debate. His most likely estimate of Earth's circumference was about 29,000 miles — close enough to the current value of about 25,000 miles to command our admiration.

Of course, there were problems with Eratosthenes's method. Syene is not due south of Alexandria (as it would have to be for his method to work). Furthermore, the distance between the two is about 4,530 stades, rather than 5,000. Nevertheless, Eratosthenes's feat demonstrates the power of clear reasoning.

A similar lesson can be drawn from the work of another Greek astronomer, Hipparchus. Born in a Greek city in what is now western Turkey, he did most of his astronomical work on the island of Rhodes in the Aegean Sea. (He died there sometime around 127 B.C.) He was one of the greatest, if not the greatest, of the ancient astronomers. Until recently, some scholars argued that Ptolemy had merely copied Hipparchus's writings to create the *Almagest*. It is disappointing that we know so little about him or his life. The only surviving anecdote (of doubtful veracity) is that on one clear evening he once wore a cloak to a theater performance in Rhodes because he had predicted a storm.

Hipparchus's contributions to astronomy were prodigious. He was the first to record the positions of stars in the sky. (He apparently claimed he did so to be able to tell time at night — another first.) To honor Hipparchus's work, the European Space Agency named a satellite for him that was used to determine the positions of stars to unprecedented accuracy.

**Like all giants of science, Copernicus built on the work of those who came before him.**

## *Earthly Precessions*

Hipparchus also compiled eclipse records from Babylonian astronomers and used them with other measurements, according to Pliny the Elder, to predict eclipses hundreds of years in the future (modern scholars sometimes dispute this claim). But his greatest fame rests on two discoveries: the so-called precession of the equinoxes and his partially successful attempt to determine distances between objects in the solar system and their sizes.

The precession of the equinoxes is understandable if we think of Earth as revolving around an axis that tilts about 23° from the plane of its orbit, called the ecliptic. Furthermore, the axis of rotation isn't fixed in space but wobbles like a spinning top. In this way, Earth completes one wobble in about 26,000 years. This precession makes true north move away from the North Star. In 13,000 years, for example, our North Star won't be Polaris. It will be Vega. In 26,000 years, Polaris will again be the North Star. This precessionary wobble has other consequences. For example, the position of the sun with respect to the stars at the spring and fall equinoxes also appears to move around the sky every 26,000 years. It was this subtle motion that Hipparchus detected with his careful measurements and historical records.

Hipparchus achieved his greatest impact with his estimates of the sizes of the sun and moon and the distances that separate them from Earth. Estimating these distances continued through millennia and continues in the quest to measure the basic dimensions of the universe.

On March 14, 190 B.C., an eclipse of the sun occurred in the Middle East. Comparing the angle of sight to the moon from a spot near the present location of Istanbul with the angle measured at Alexandria and using some simple geometry, Hipparchus concluded that the distance to the moon on that day was about 71 times the radius of Earth. (That's not bad — the currently accepted value of the Earth-moon distance is about 60 times Earth's radius.) He was less successful in estimating the distance to the sun — his value was 490 Earth radii or 194,000 miles, while the actual distance is roughly 93 million miles.

There is a legend that Hipparchus's ability to predict eclipses was foreshadowed by one of his predecessors, Thales of Miletus. Called the "Father of Science," Thales was the first to apply the questioning, naturalistic mode of thought we identify with modern science to a wide range of topics. His students, for example, devised the familiar Earth, fire, air, and water system of explaining the properties of materials. We know little about Thales. According to legend, he fell into a ditch because he was looking up at the stars. He supposedly stopped a battle between the Medes and the Lyrians with his prediction of an eclipse in 584 B.C. Most modern scholars discount the eclipse-prediction story because the techniques needed to predict eclipses were developed hundreds of years later.

## *Heliocentric Heresy*

A heretical, minority opinion united a few ancient astronomers: Earth is not at the center of the cosmos but instead orbits the sun with the other planets. Unfortunately, the documents that support these theories vanished like the people who produced them. All we have are comments made later by writers whose works survive. The notion of a sun-centered system seems to have started with the followers of Pythagoras. He argued that since fire was the purest element, it should be located at the position of pride, in the center of things. Some versions of this theory were truly bizarre — in one, a flat Earth rotated in orbit around the central fire in such a way that the uninhabited side was illuminated. In this creative picture, the sun was apparently a secondary fire that also orbited the center.

But the scientist universally credited by ancient authors with producing a sun-centered theory was Aristarchus of Samos (310–230 B.C.). The only surviving work of Aristarchus, a book called *On the Sizes and Distances of the Sun and Moon*, shows no hint of heliocentrism, so his theory may have been developed in a manuscript that was lost. Archimedes writes in his *The Sand Reckoner*: "[Aristarchus's] hypotheses are that the fixed stars and the sun are stationary, and that Earth is borne in a circular orbit around the sun."

This sounds convincing to me. But arguments like those advanced by Ptolemy weighed heavily against this viewpoint in the ancient world, as did the religious conviction that the home of humanity had to occupy the central spot in the universe. Among astronomers, another argument was important: If Earth moves in a circle, the stars should appear to move in the sky from one season to the next. This so-called stellar parallax is easily seen with modern telescopes but could not be seen with instruments available in antiquity.

Aristarchus's argument that the stars were too far away for us to see parallax, though it ultimately proved correct, was rejected as special pleading by his contemporaries. They were right to question it. There was precious little evidence to support the sun-centered universe and many reasons to reject it. Relying on someone to introduce a new and totally unsupported idea to save the theory was no more convincing to ancient astronomers than it would be to astronomers today.

Scientists see these kinds of arguments all the time, and they almost always have an aura of grasping at straws. The chance that any one of them may prove to be right centuries down the road is pretty slim. So in the end, I would be reluctant to include a heliocentric universe in my list of the accomplishments of ancient astronomers.

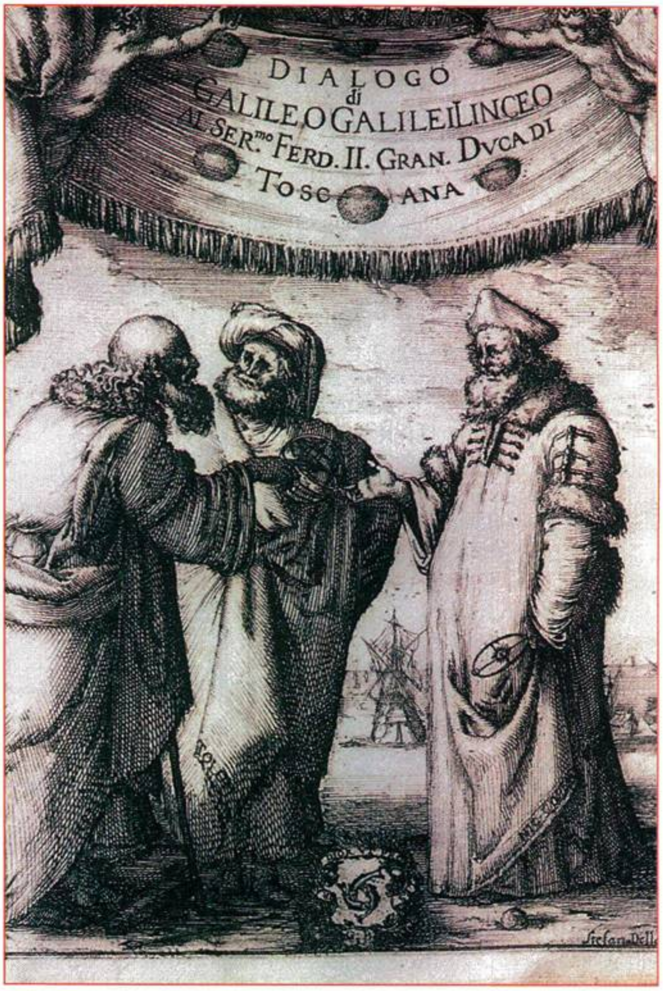
## *The 1,400-Year Gap*

However, as we have seen, the list is impressive without it. But contemplating that list brings us to another, and potentially more interesting, question: Why, given all this knowledge, did astronomy need the Renaissance to be reborn? Why, in other words, was there a 1,400-year gap between Ptolemy and Copernicus?

The short answer to this question is that there wasn't — that the notion of a gap results from too narrow a view of history. While Europe was sinking into its Dark Ages, the compilation of astronomical knowledge in Ptolemy's book became the basic working tool of Arabic astronomers. They spent centuries refining their observations and producing commentaries on the *Almagest.* When Gerard of Cremona translated the book from Arabic to Latin in 1175, the main corpus of ancient astronomy once again became available in the West and, along with the works of Aristotle and Plato, was quickly incorporated into universities' curricula.

The Polish cleric and political leader Nicolas Copernicus (1473–1543), the person generally reckoned to be the founder of modern astronomy, studied the *Almagest* closely. It was the custom at the time of Copernicus for men like him to have an intellectual hobby. He asked a simple question: Is it possible to explain the data compiled by Ptolemy with a system in which the sun, rather than Earth, is at the center of the universe?

Most of the data he used was from the tables in the *Almagest,* supplemented by a few observations of his own. The mathematics at Ptolemy's disposal and the type of reasoning he used would also have been available to any scholar after him. Copernicus' great achievement was to take the then-outlandish notion of heliocentricity and develop it to the point where it could be compared, exact prediction to exact prediction, to Ptolemy's Earth-centered universe.


DIALOGO
di
GALILEO GALILEI LINCEO
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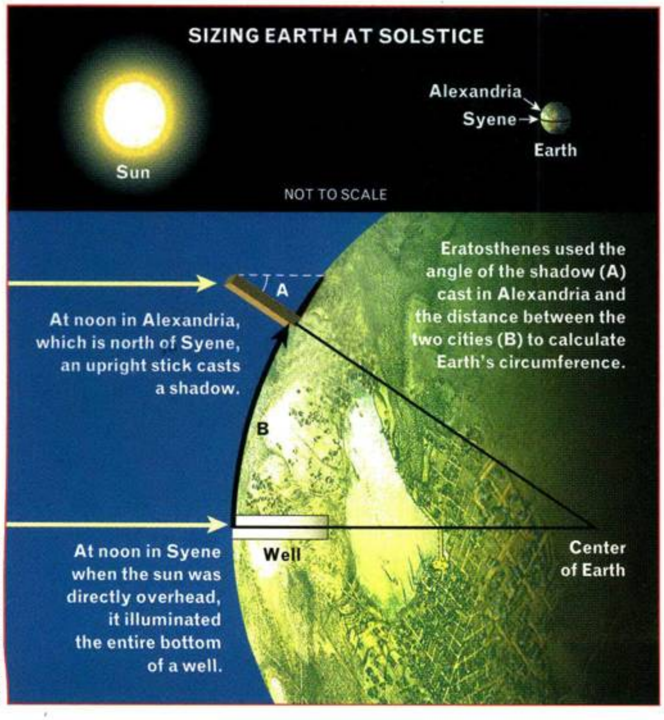
**The frontispiece of Galileo's *Dialogue Concerning the Two World Systems* (1632) shows Aristotle, left, Ptolemy, middle, and Copernicus (drawn with Galileo's head).** Jay M. Pasachoff


SIZING EARTH AT SOLSTICE
Sun
Alexandria
Syene
Earth
NOT TO SCALE
Eratosthenes used the angle of the shadow (A) cast in Alexandria and the distance between the two cities (B) to calculate Earth's circumference.
A
At noon in Alexandria, which is north of Syene, an upright stick casts a shadow.
B
At noon in Syene when the sun was directly overhead, it illuminated the entire bottom of a well.
Well
Center of Earth

*Astronomy:* Elisabeth Rowan

Like all giants of science, Copernicus relied on the work of those who came before him, including Ptolemy. For example, in order to explain the motion of planets, Ptolemy said they were attached to small crystal spheres called epicycles. These epicycles rolled around on larger crystal spheres in the sky. Copernicus's model also had the planets, including Earth, moving around on epicycles. When critics objected to a rotating Earth, Copernicus was quick to point out that rotation involved motion within a circle, the perfect geometrical form. This was a classic and medieval argument, but hardly a scientific one.

Copernicus took the universe bequeathed him by the ancients and transformed it by asking a fundamental question. He didn't give us a modern understanding of the universe, but he placed us on the road leading toward it. His single insight changed forever the way we viewed the universe and our place in it. What better tribute to the work of the ancient astronomers? ■

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*Astronomer and science writer James Trefil is a member of* Astronomy*'s editorial advisory board.*

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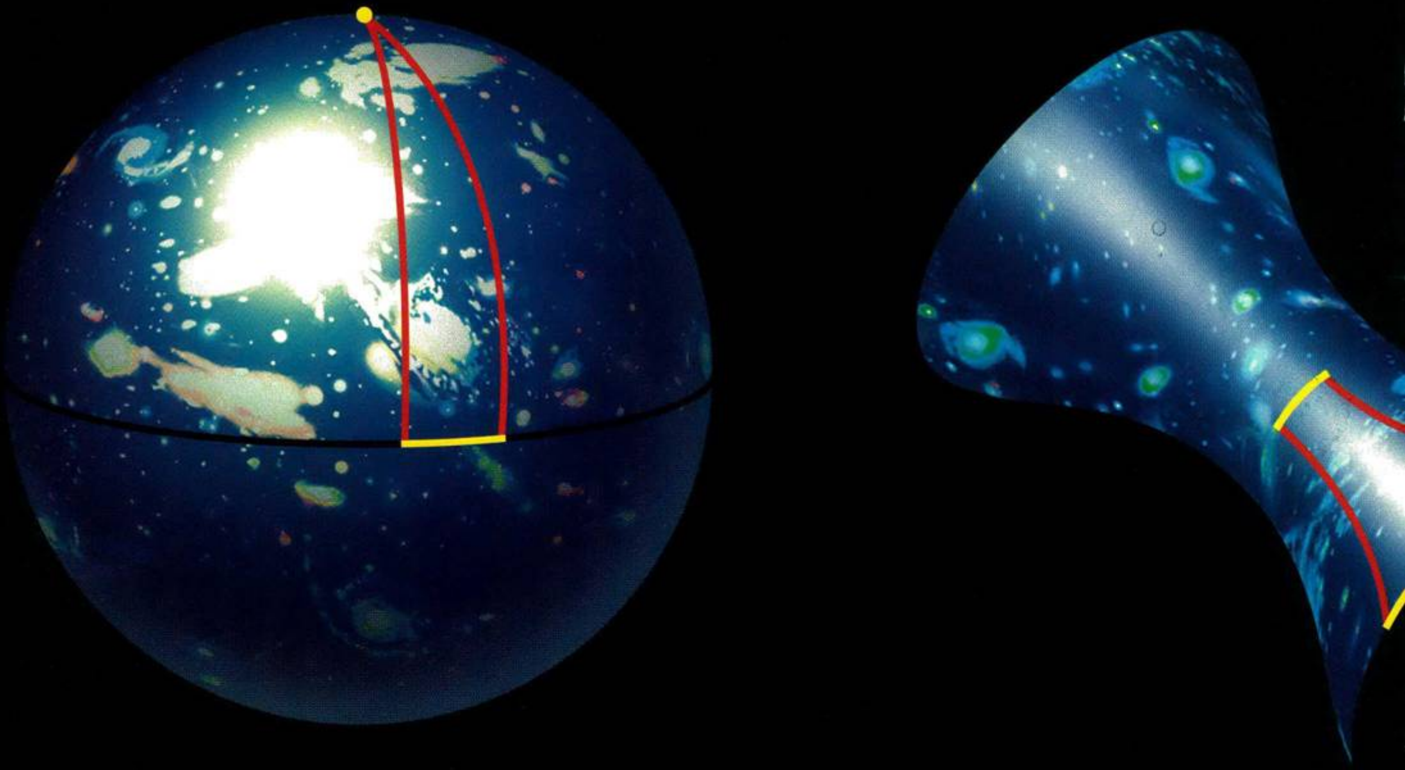


# UNVEILING THE

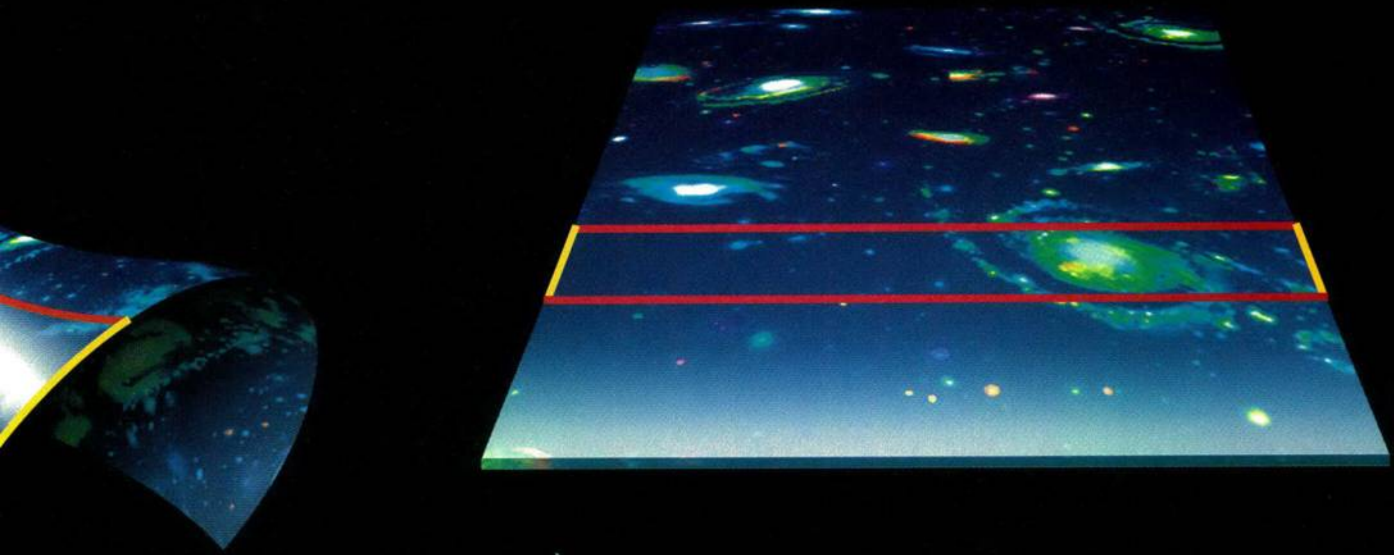
*New observations of the cosmic microwave background suggest that the universe is flat and will expand forever at an accelerating rate.*

**by Diana Steele**

A suite of ground-based, balloon-borne, and Earth-orbiting telescopes is setting out to learn the song of the universe's creation. As these telescopes tune into the cosmic symphony, cosmologists are on the verge of sounding out some of their most cherished theories about how the universe formed and evolved.

The first pitch has sounded loud and clear. New findings reported by two international teams in April and May confirm one of cosmologists' major theoretical predictions: that the universe experienced an instant of hyperexpansion moments after its birth, violently stretching the fabric of spacetime until it was perfectly flat.

The key to the cosmic symphony is the cosmic microwave background radiation — the glowing ember of the Big Bang's fireball. The microwave background gives cosmologists a snapshot of the universe at age 300,000 years. "There is no older light in the universe," says Princeton University cosmologist Lyman Page. In contrast, the most distant objects in the Hubble Deep Field emitted their light hundreds of millions of years after the Big Bang.



*Astronomy:* Elisabeth Rowan

**From left to right, the universe can assume either a closed, open, or flat geometry. In a closed universe, parallel lines eventually cross; in an open one, parallel lines diverge; in a flat universe, parallel lines never meet.**

# FLAT UNIVERSE

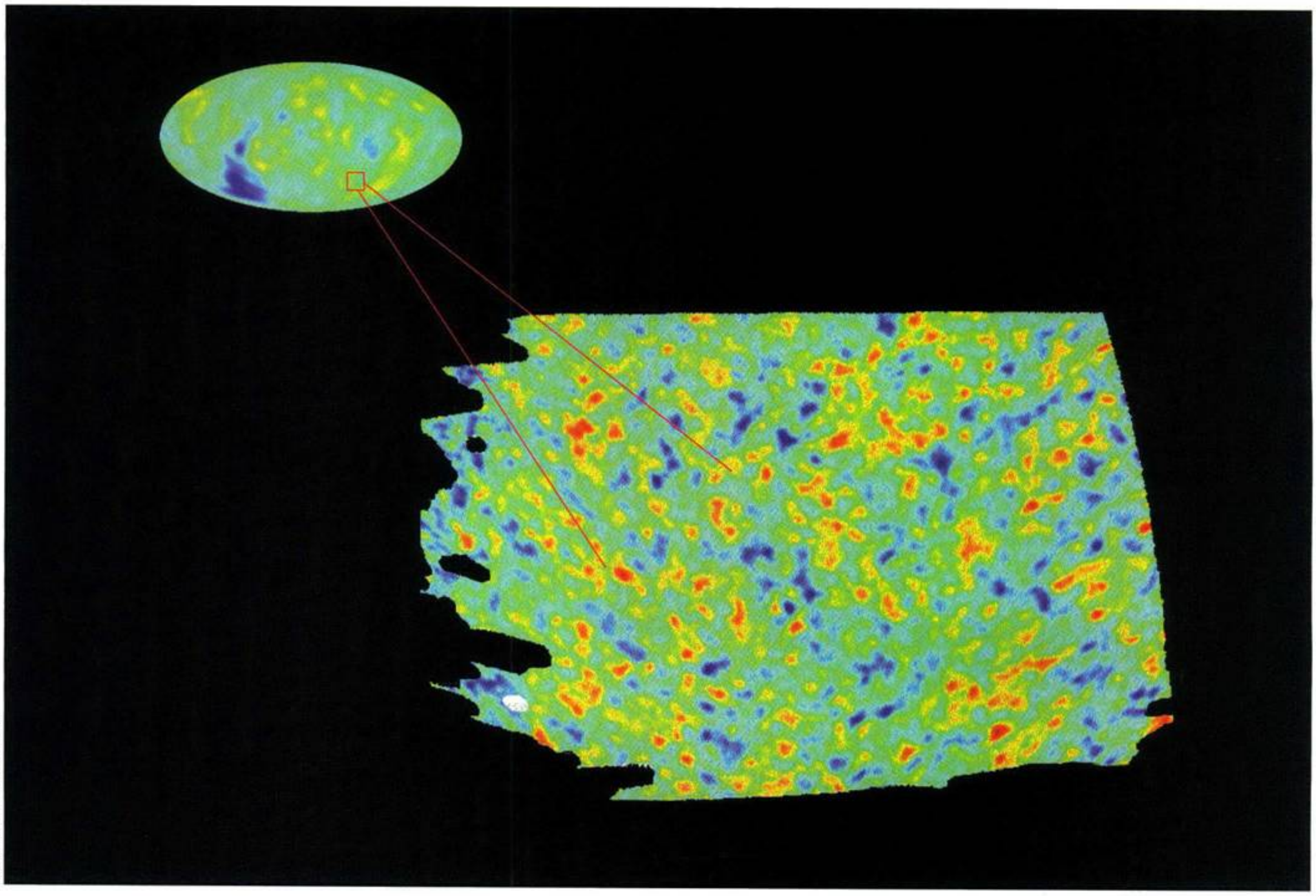
## ROLLING BACK THE CLOCK

Arno Penzias and Robert Wilson of Bell Labs accidentally discovered the microwave background in 1965 when they noticed a hiss of microwaves (high-frequency radio waves) coming from all directions. "If you looked at the sky with microwave eyes, you'd see a uniform glow," explains Mark Dragovan of NASA's Jet Propulsion Laboratory. "If you had sensitive eyes, you would see that it's brighter in one direction than the other due to our galaxy's motion relative to the background. And if you had really sensitive eyes, you would see brighter patches and darker patches about as wide as the full moon."

The origins of the microwave background and its patches can be traced back to the early moments of the universe. If you could watch a movie of how the early universe unfolded, this is what cosmologists think you'd see:

A tiny fraction of a second after the Big Bang, the currently observable universe is a trillion times smaller than a proton and fantastically hot and dense. But a split second later, it begins to expand faster than the speed of light. In a mere fraction of a second, the universe expands proportionally more than it will in the next 15 billion years. This "inflation" stretches the fabric of spacetime to an enormous size, making it appear flat on large scales.

At the time of inflation, the universe is so hot that matter exists only as a hot plasma of fundamental particles. But



BOOMERANG Collaboration

**Data from the COBE satellite (top) could only reveal hot and cold patches about 7° across. BOOMERANG's data could resolve 1° patches, which are the signs of inflation.**

the plasma isn't entirely smooth. Inflation stretches tiny variations that exist on subatomic scales to astronomical sizes. This makes the plasma lumpy, like bad gravy.

Gravity tries to make high-density lumps contract. But the plasma fights back. Photons of light bounce around the plasma like light in a hall of mirrors, generating a collective pressure that keeps matter from compressing. For hundreds of thousands of years, this fight between gravity and light sends sound waves racing through the plasma at about half the speed of light.

During this era, the plasma is so hot and dense that electrons float freely, scattering light before it can travel far. The universe is opaque. But about 300,000 years after the Big Bang, the universe finally cools enough so electrons can combine with protons to form hydrogen atoms. Suddenly, light can travel freely and the universe becomes transparent. The light has a temperature of about 2700° C (4900° F). Over the next 12 billion to 15 billion years, the universe's expansion stretches out (redshifts) and cools this radiation to –270° C (–455° F). That's only 2.73° C (4.91° F) above absolute zero. The radiation appears to Earthlings as an omnidirectional din of microwaves.

Tiny temperature variations in the microwave background are the record of the ripples in the plasma. Cooler spots correspond to the high-density lumps. In these regions, gravity "pulled back" on the radiation, redshifting the light and making the microwave background appear slightly cooler in those directions. These denser regions are the seeds that evolved into the clusters and superclusters of galaxies that we see today. Hotter spots would go on to become immense voids. Figuring out the pattern of the ripples is the key to understanding whether inflation occurred and how much matter the universe contains.

## IT'S A FLAT WORLD AFTER ALL

In the early 1990s, NASA's COBE (Cosmic Background Explorer) satellite finished mapping the microwave background across the entire sky. In a headline-grabbing announcement, COBE principal investigator George Smoot confirmed that subtle ripples exist in the otherwise uniform microwave background — the first hint that theorists were on the right track. But the ripples seen by COBE were about 7° across, the width of 14 full moons. COBE's resolution wasn't sharp enough to see ripples corresponding to the seeds of galaxy clusters, nor could it tell if inflation occurred.

Over the next decade, astronomers deployed a number of ground-based and balloon-borne telescopes around the world to tune into the microwave background. These experiments had sharper resolution than COBE and their observations showed that hot and cold spots averaged about 1° in width (two full moons) — in line with the predictions of inflation. But only recently has the vast increase in computing power and more sensitive detector technology combined to make detailed observations possible.

In late April, an international team led by Andrew Lange of Caltech and Paolo de Bernardis of the University of Rome, La Sapienza, announced it had made the most detailed map yet of the cosmic microwave background. The team made its discovery with a $4-million balloon-borne experiment known as BOOMERANG (for Balloon Observations of Millimetric Extragalactic Radiation and Geophysics).

BOOMERANG mapped only three percent of the sky during a 10½-day circumpolar flight around Antarctica in December 1998 and January 1999. But with a 1.2-meter telescope and bolometric detectors chilled to a fraction of a degree above absolute zero, BOOMERANG could resolve ripples 35 times smaller that those seen by COBE.

BOOMERANG found hundreds of hot and cold spots that varied from the average temperature by a paltry 0.0001° C. More important, these spots average about 1° in width. The BOOMERANG results agree with previous experiments and with inflationary theory. Inflation predicts that the geometry of spacetime is flat, and in such a flat universe, the longest sound waves in the early universe would appear today as hot and cold spots about 1° across. "It is an incredible triumph of modern cosmology to have predicted the basic form so accurately," says Lange. Adds University of Chicago theoretical cosmologist Michael Turner, "It is truly amazing that our little pencil scratchings on paper have something to do with what's actually going on out there."

In Einstein's general theory of relativity, space curves around massive objects. In a closed universe, there is enough mass and energy so that space as a whole curves until parallel lines will eventually meet. An open universe, which has much less mass and energy, curves in the opposite direction, and parallel lines seem to diverge. Hot and cold spots about 1° across mean that the microwaves in the background radiation would remain parallel almost all the way across the universe. There's just enough mass and energy to keep the universe flat. With flat, Euclidean geometry, parallel lines don't curve in either direction.

The BOOMERANG results, added to data from two supernova experiments first reported in 1998, strongly support the startling notion that some kind of "dark energy" is causing the universe's expansion rate to accelerate. Astronomers use the Greek letter omega (Ω) to signify the density of mass and energy in the universe. If the universe is flat, omega should be exactly 1. Astronomers have found that about five percent of the mass and energy needed to make omega equal 1 is in the form of "baryonic" matter — stuff made out of atoms such as stars, planets, and people. About 30 percent of omega is dark matter, perhaps relic particles from the Big Bang that surround galaxies like our own in massive halos. In other words, matter accounts for only about 35 percent of the mass and energy needed to make a flat universe.

"It doesn't take a genius to recognize that there's 65 percent of something else," says University of California at Berkeley astronomer Alexei Filippenko, a member of one of the two supernova teams. "That something else cannot be any kind of gravitating matter. Thus, something like dark energy is a good possibility, and whatever the stuff is, it will have a repulsive effect." If most of the universe's energy takes this form, which also goes by the names cosmological constant and quintessence, the universe will expand forever.

## COSMIC OVERTONES

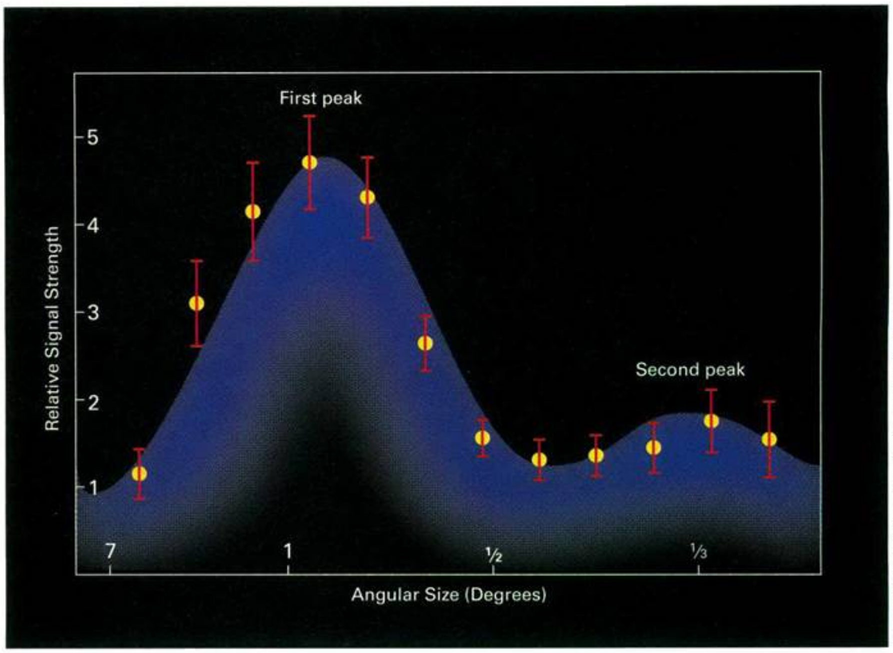
Because of the previous experiments, cosmologists were hardly surprised that BOOMERANG found a flat universe. But for cosmologists, what BOOMERANG *didn't* see is more surprising than what it did. BOOMERANG was expected to "hear" overtones from that first note. "They are overtones in the same sense that if you pluck your guitar string it can oscillate at the fundamental frequency, and then at one and two octaves above," says University of Pennsylvania theorist Max Tegmark.

Cosmologists predict a series of peaks, where the first peak is the fundamental tone at 1°, and harmonic peaks appear at smaller angular scales. But just as the exact sound of musical overtones depends on whether a flute, violin, trombone, or other instrument is playing the note, the shapes of the second and third peaks depend a great deal on parameters such as the amount of matter in the universe.

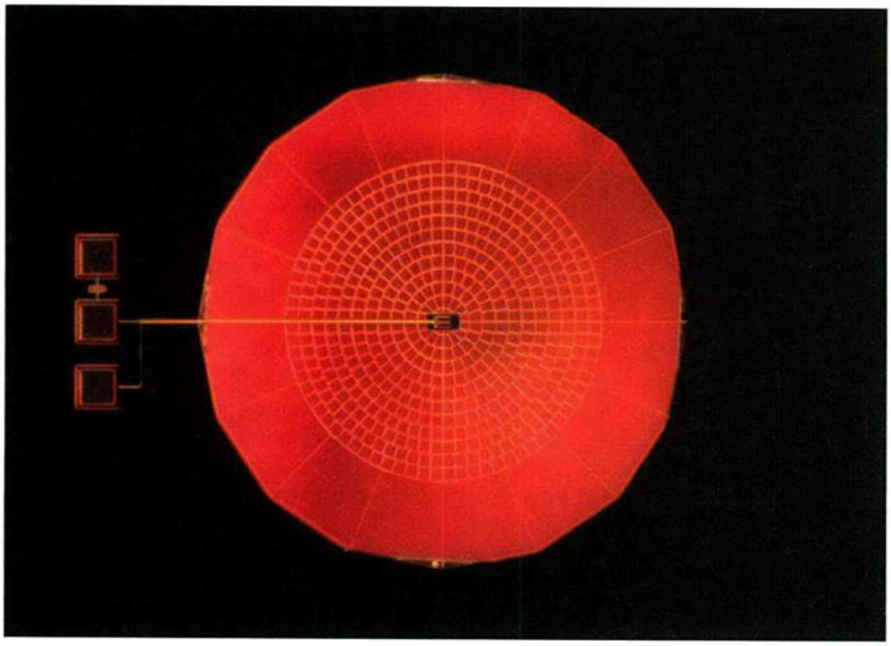
Because BOOMERANG didn't see the second peak, it looks like it's going to be a lot smaller than cosmologists expected. "The fact that it isn't there, or that it's so small that we can't see it yet, is really telling us something very interesting," says Tegmark. "My own guess is that it's telling us that there's more of our kind of stuff in the universe." That is, more baryonic matter.

In May, another international balloon experiment, MAXIMA (Millimeter Anisotropy Experiment Imaging Array), confirmed BOOMERANG's results. Because MAXIMA looks at smaller angular

**The microwave background peaks at several angular sizes where the signal is stronger. The peaks correspond to the average angular size of hot and cold spots in the microwave background. The biggest peak shows up at 1°, which is where it should be in a flat universe. The second peak is smaller than expected, which could mean there is more atomic-type matter in the universe.**



BOOMERANG Collaboration / *Astronomy*: Elisabeth Rowan



BOOMERANG Collaboration

**BOOMERANG's bolometric detectors, one of which is shown here, are so sensitive they could detect the heat of a coffee maker at the distance of the moon.**

scales, it even hinted at the third peak. The MAXIMA team, which is led by the University of California at Berkeley, flew its balloon from the National Scientific Ballooning Facility in Palestine, Texas, on August 2, 1998.

"The exciting thing is going to be to try to map out the third peak very carefully," says Tegmark. Several telescopes are poised to do just that.

## THE RACE IS ON . . .

BOOMERANG is one of several telescopes that take advantage of Antarctica's cold temperatures and dry air. Water vapor in the air absorbs microwave radiation, and Antarctica is one of Earth's driest deserts. The BOOMERANG balloon also took advantage of Antarctica's circumpolar winds. Just like its namesake, BOOMERANG took off and landed in virtually the same place. After circumnavigating Antarctica at 120,000 feet (36,000 meters), the balloon landed just 30 miles (50 km) from where it took off. The telescope will fly again in December 2001.

But it won't be alone. BOOMERANG will have company in the form of another Antarctic balloon-borne telescope called TopHat. This telescope — built by an international team led by NASA's Goddard Space Flight Center — has one important advantage over BOOMERANG. Whereas BOOMERANG's telescope was suspended from a balloon, TopHat's telescope rides on top of a balloon (hence the name), so it can see a lot more of the sky without light scattering off its supporting structures. This means TopHat can get a better idea of what the symphony sounds like.

More contributions should soon come from DASI (Degree-Angular-Scale Interferometer), a ground-based telescope made up of 13 small antennae, or horns, arranged in a pattern on a large platform. These horns, each only 8 inches in diameter, work together to make an extremely sensitive telescope.

DASI was set up at the South Pole — a 10,000-foot plateau — in January 2000, and will take data continuously throughout the long Antarctic winter. Even one month of data will revolutionize the current picture of the cosmic microwave background radiation. "BOOMERANG and MAXIMA have left a nice niche for DASI, which is to really zero in on the range where the second and third peaks in the spectrum are supposed to be," says team leader John Carlstrom of the University of Chicago.

A sister experiment to DASI, the Cosmic Background Imager (CBI), is looking for harmonics at higher octaves from a mountainside in Chile. And MAXIMA, which flew for a second time in June 1999, is set to fly again this fall.

## THE GOLD MINE

Early next year, NASA will launch another satellite dedicated to studying the cosmic microwave background. Called MAP (Microwave Anisotropy Probe), this telescope will provide the first high-resolution, all-sky map of the cosmic microwave background. MAP will orbit far from Earth, so it won't have to measure tiny temperature differences with a warm Earth sitting right next to the telescope. "It will be a giant leap forward from all previous experiments," says MAP collaborator Lyman Page, who adds that MAP will resolve some nagging discrepancies between BOOMERANG and MAXIMA.

In about 2007, the European Space Agency will launch the Planck satellite. Planck covers a wider range of frequencies than MAP and has twice the resolution. Planck will detect peaks beyond the first three or four, if they are there.

Tegmark says people have been asking him why go ahead with the satellite experiments when there's so much good data coming in from ground-based and balloon-borne telescopes. "Why build a gold mine after finding a vein of gold? To suddenly stop now would be absolutely crazy," he says. "We've begun to get a feeling for the landscape. We can start saying really interesting stuff about the composition of the universe, but it's still really just beginning."

With the BOOMERANG results fitting the new cosmology like a glove, and with progress being made on several fronts, some people might wonder if cosmology is on the verge of being solved. Michael Turner emphasizes that it's not time for a coronation. Scientists still don't know the nature of dark matter, nor do they have a clue about dark energy other than it causes the universe's expansion to speed up.

Still, some cosmologists worry that they might have to start looking for a new line of work if their theories are too successful at matching observations. "I'm hoping that we've got it all wrong," jokes University of Chicago cosmologist Stephan Meyer, who works on both TopHat and MAP. "Sure, it would be mighty cute if everything worked out just as we thought. But of the two extreme possibilities, I'd rather have it all be wrong."

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*Freelance science writer Diana Steele recently moved to San Diego and is still getting used to salt water. Her previous* Astronomy *feature, "Surviving in Space," appeared in the October 1999 issue.*

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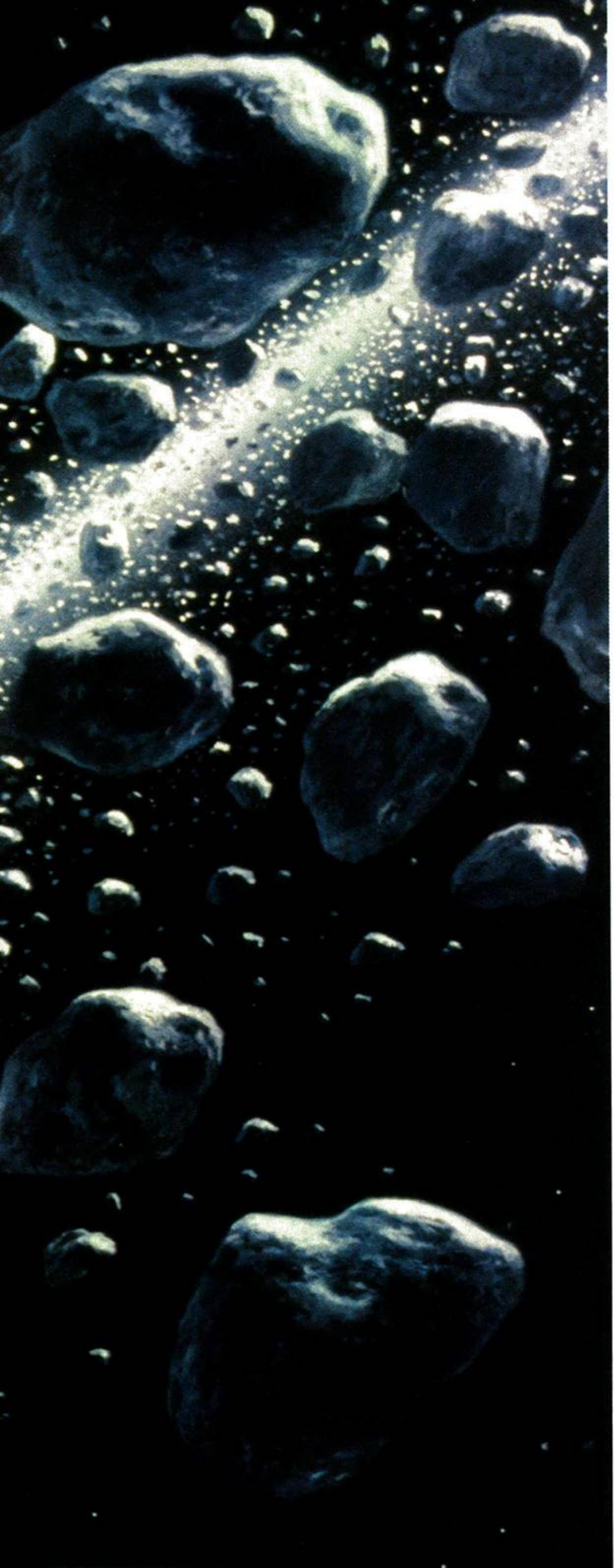


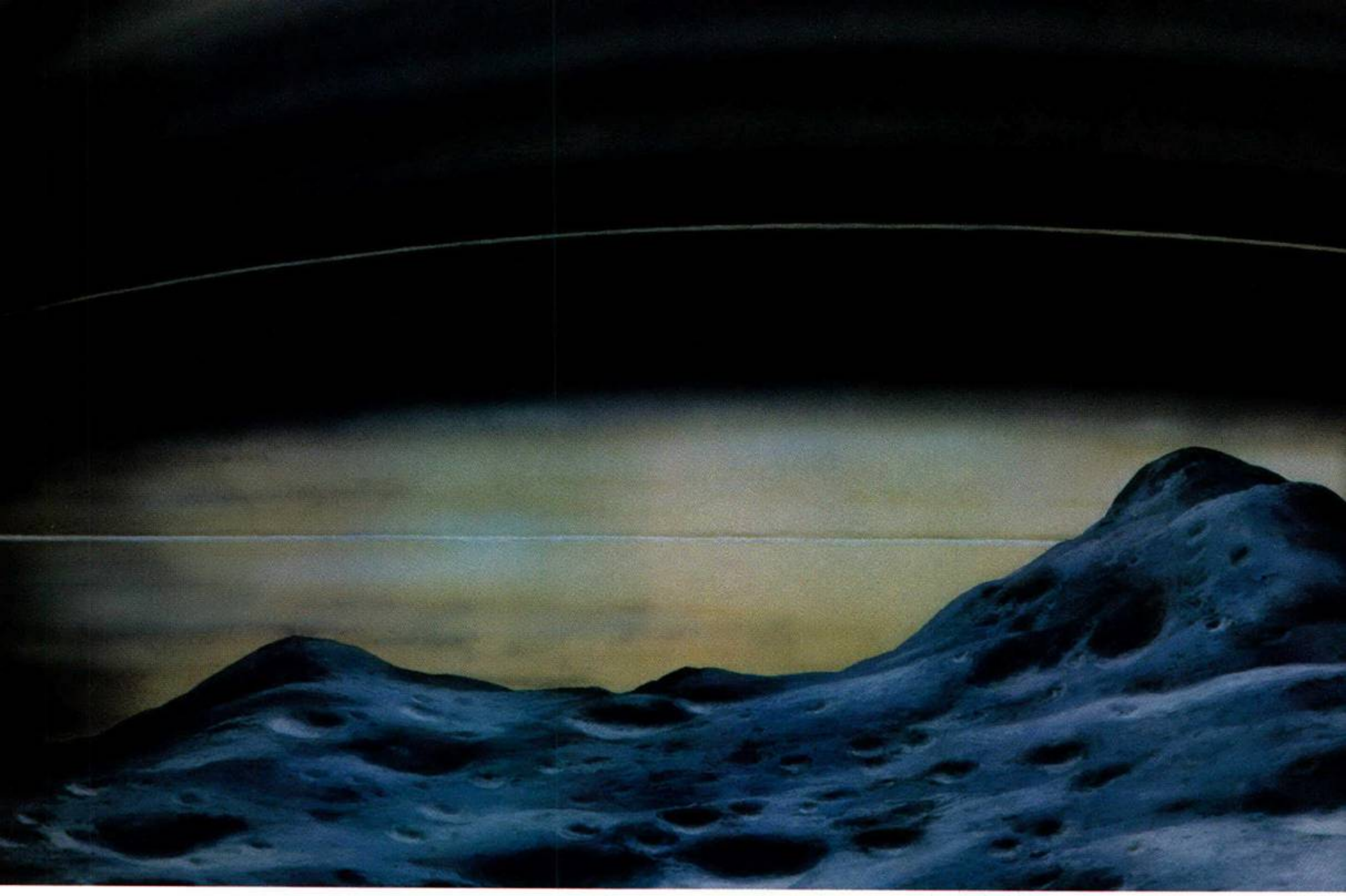
# PAINTING THE CONTOURS OF SPACE

## *Ludek Pesek explored the solar system with a paint brush.*

**Text by William K. Hartmann**
**Paintings by Ludek Pesek**

In the 1960s, American readers began to encounter a series of vivid paintings of other planets in magazines such as *National Geographic* and books such as *Planets of the Solar System*. These images were created by a Czech painter who lived in Switzerland: the late Ludek Pesek. Pesek was little known then in the United States but is legendary now — among those who follow the history of space exploration. In the heady days of the first space flights, the paintings intrigued and inspired a generation of young readers; many of my own colleagues in planetary exploration today recall being excited by these works when they were students.

**Ludek Pesek created many impressions of space that first appeared in *National Geographic* magazine, including *Ice Bodies in Saturn's Rings.*** All photos by William K. Hartmann



Who was Ludek Pesek? Before he died of a heart attack in late 1999, I had an opportunity to fulfill a long-time dream of meeting Pesek and his wife Beatrice in their apartment outside of Zurich. Pesek had been a hero of mine for his space paintings alone, but I learned that behind those images was a much richer life than I had imagined, full of astronomical interests and creative adventure.

Pesek was born in 1919 in the then-new country of Czechoslovakia and grew up in the town of Ostrava, about 160 miles from Prague. As a young man he studied art, but he also enjoyed observing the planets with his own backyard telescope. He devoured science fiction books, such as the works of Jules Verne, and started to paint astronomical scenes in high school. Among his earliest creative works were three novels, published in 1946–48 in Czechoslovakia.

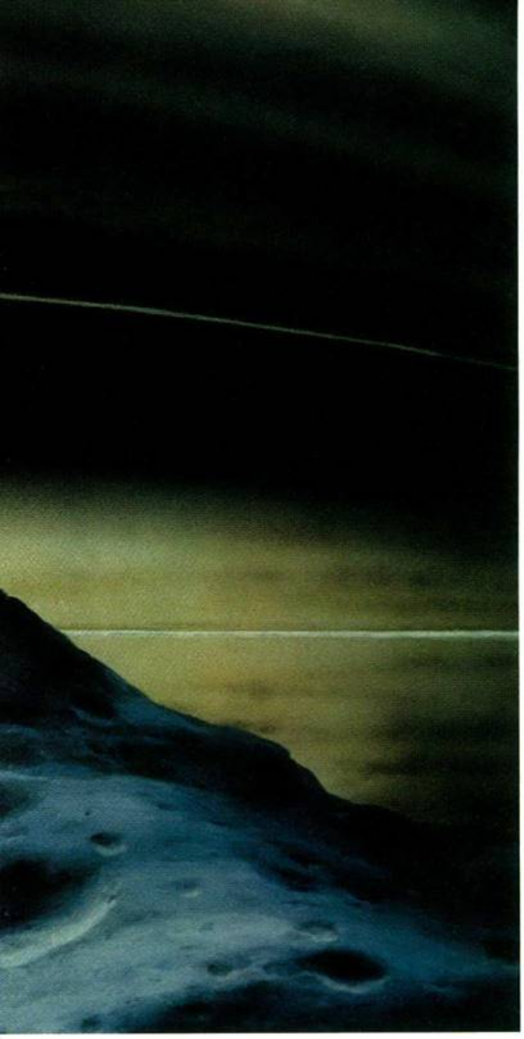
The climate of the country changed at that time, when it became a communist satellite of the Soviet system. Pesek, as a well-known artist, was soon pressured to join the party and become an active member of the Union of Artists. Under the Soviet system, unions of artists, writers, and composers offered many perks and chances for exhibition and publication, but at the same time gave government officials extraordinary power over the arts. Works of "unreliable" artists, critical of the system, could be ignored if the artist were on the wrong side of the bureaucracy. Pesek kept turning down the official encouragement to join but was able to continue his career.

The pressure on Pesek continued for years until Prague Spring — the liberalization movement that lasted from 1965 to 1968. At that time, restrictions on publication and travel eased. "Communism with a human face" was evolving. Pesek was able to release several more books, such as a photo essay on Lebanon (1965), a young readers' illustrated novel, *Moon Expedition* (1967), and an illustrated book, *Planet Earth* (1967). Reveling in the new, freer, international climate, Pesek and his wife Beatrice made their first trip to Paris in 1965 to visit the Louvre and "all the museums we could find."

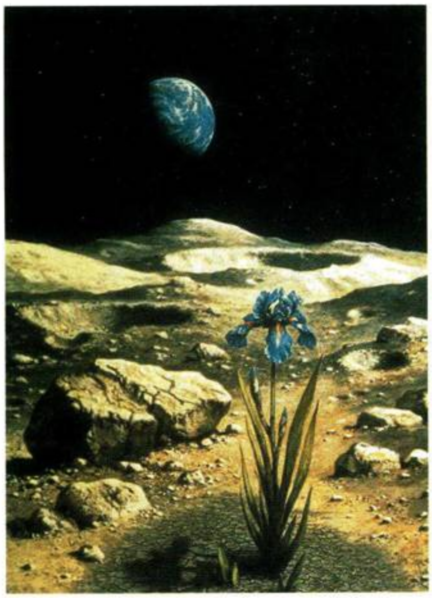
**Above: Pesek interpreted Saturn as it might be seen from its moon, Mimas. Top Right: In the surrealistic style of Russian space artists, Pesek often included an earthlike plant on the surface of a foreign object, as he did in *A Flower on the Moon.* Right: Pesek painted 50 impressions of America in a series called *Virgin Forests in the USA.***

In 1968 they made a fateful second trip abroad. At this time the Soviet officials felt they were losing control of the Czech situation; the Peseks found themselves in Switzerland when Soviet tanks rumbled into Prague and party officials took over. The Peseks knew they would be in trouble for their history of thumbing their noses at the party apparatus and decided to make a new life in Switzerland.

I grilled Ludek about this moment, so foreign to the American experience. "What did you have with you, to start your new life?" Ludek shrugged and pointed to his sweater. "A sweater, a shirt. One or two suitcases." But there was one stroke of good fortune. Beatrice had been working for a Swedish firm in Prague, and her manager was able to arrange another job in Zurich



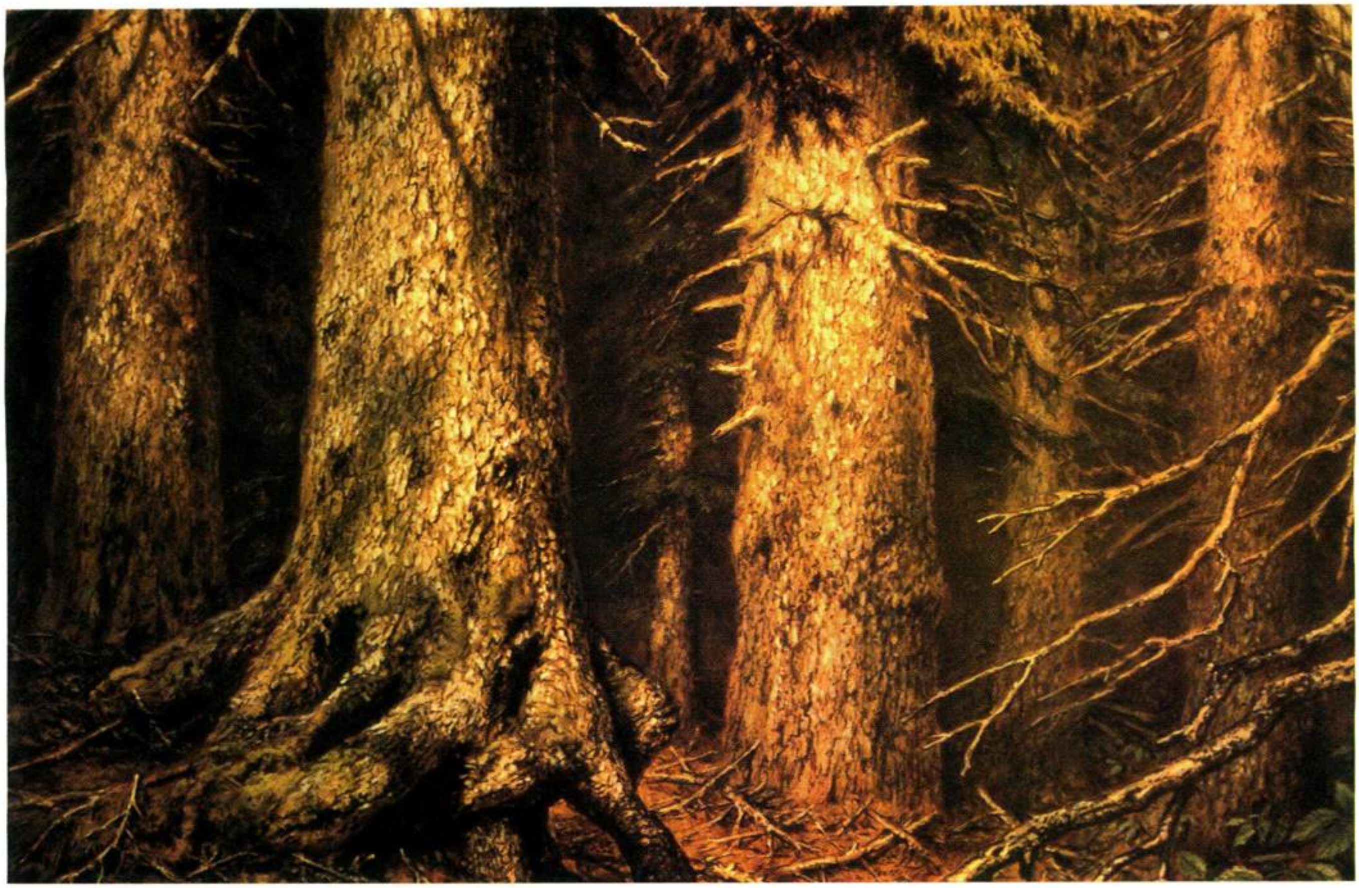
where they settled into an apartment. With this security, Ludek was able to continue his painting and writing. He started with abstract pictures — the style accepted by critics in the west, an establishment sharing such a pervasive aesthetic paradigm that it might as well be called the Euro-American "Union of Artists." Why did his art move into this area? "I was like a ship on a new ocean. I wanted a new direction."



Pesek soon found this type of work empty of meaning or ideas. By 1969, several of his books were republished in the United States, and the high-paying National Geographic Society engaged him to illustrate articles on the planets in 1969–70. More novels, planetary atlases, and illustrated books about planets followed in the 1970s, along with exhibitions of paintings, culminating in a 1981–85 series of paintings, *The Planet Mars*, based on the best scientific research. When asked how he decides to paint or write, he said: "A painting is static and fixed. With writing, I can give my ideas movement."

By the 1980s, with space becoming a known frontier, Pesek's work turned back to landscapes. His apartment was filled with gorgeous, impressionist views of his Czech homeland. He worked in both oils and acrylics. He preferred oils for his landscapes, and he associated acrylics with the greater precision that he wanted for the paintings intended for reproduction as illustrations. In the 1980s he made a series in muted, earthy colors, based on his American travels: 50 views of *Virgin Forests of the United States*.

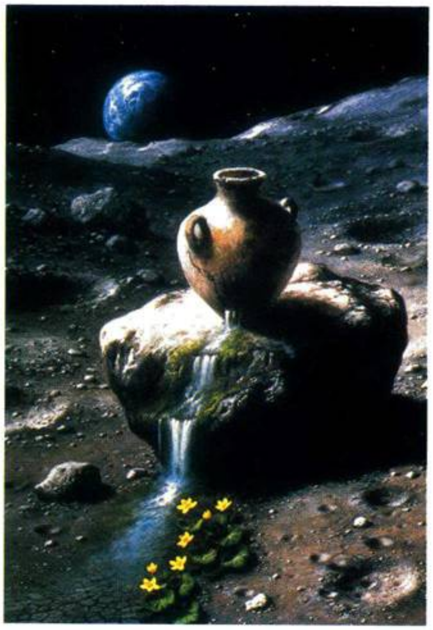
Pesek's work has also featured a series of whimsical and surrealist views

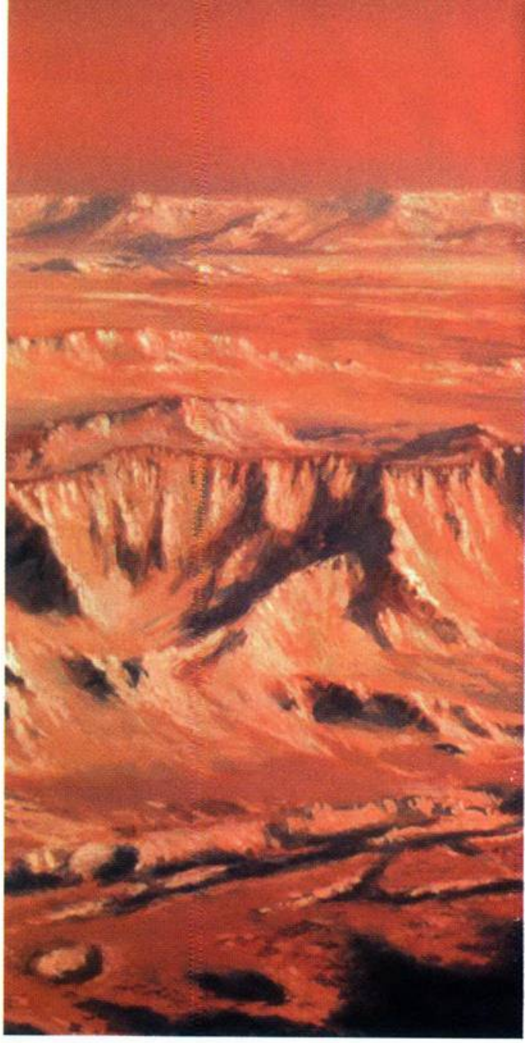


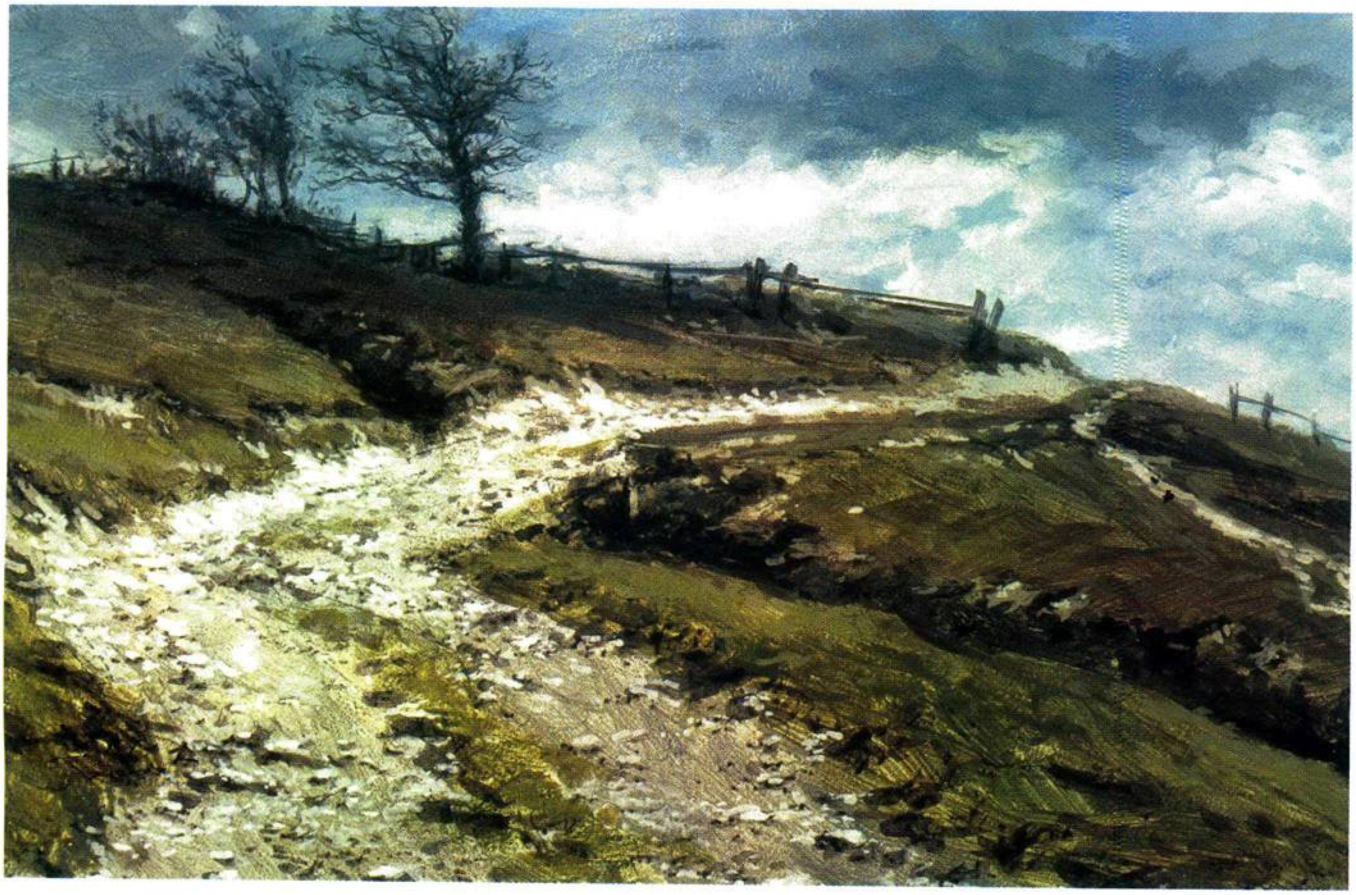
of mysterious temples, rocks, stairs, or islands floating above landscapes and seascapes. He began this series before he was aware of Magritte's similar famous view of a rock floating above the sea — an image he first saw in the offices of *National Geographic.*

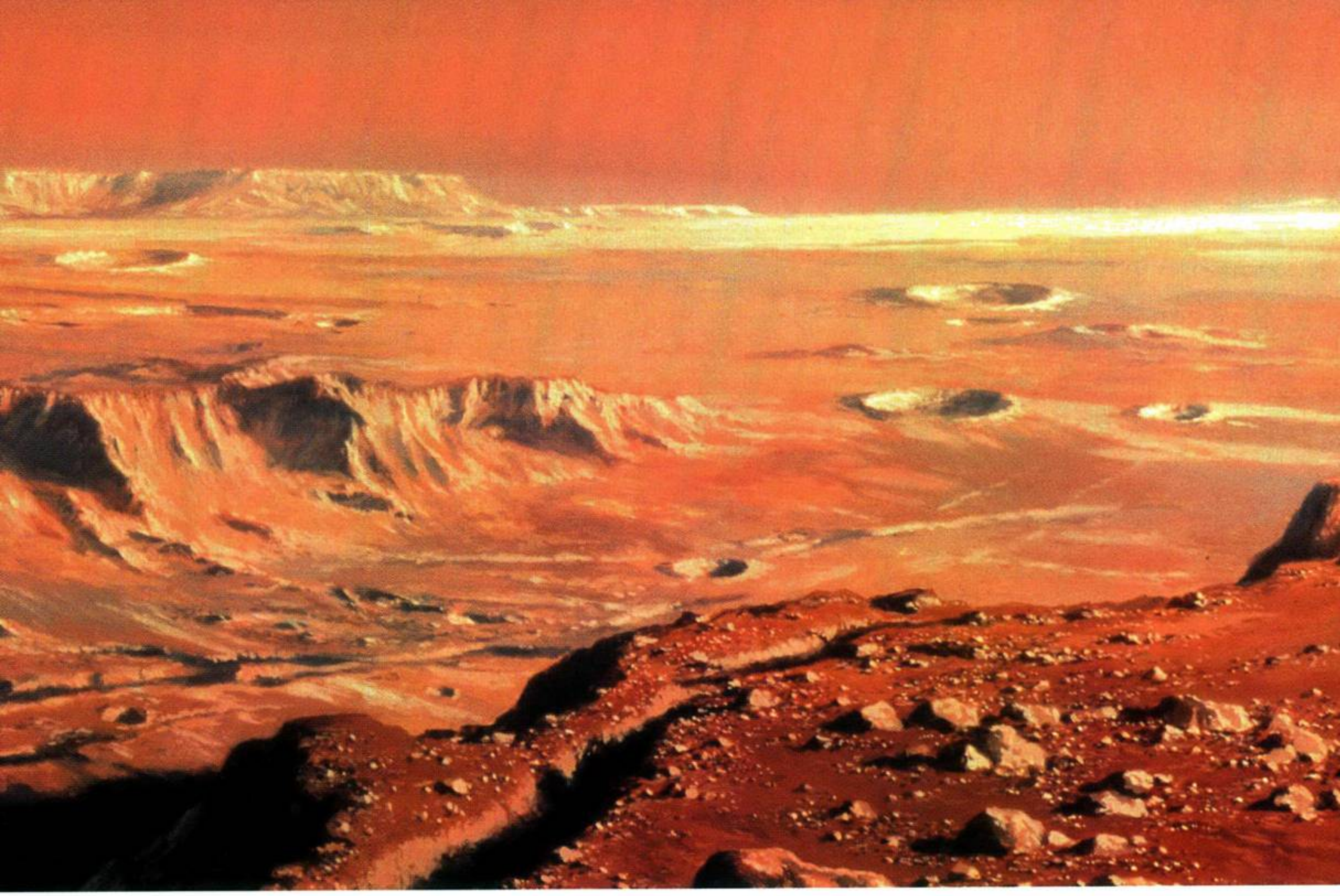
Until just before his death, Ludek remained active and enthusiastic, working in an atelier next door to his apartment. When I visited, Ludek, then 78, jumped up on a chair to bring down a book from the top shelf. I was especially interested in his range of approaches to paintings about space. I had already noticed differences in the space art traditions of United States and Russia, which perhaps reveal deep-seated national responses to the cosmos we all share. The American approach tends to be realist, with a sense of wonder about the alien lands and skies; this sensibility was pioneered by Chesley Bonestell, father of American astronomical art. Russian artists tend to be romantic and symbolic about space; ghostly images of Yuri Gagarin or angels might hover in the background of a Russian spacescape. Russian artists told me: "You Americans paint only the real surface of the moon or Mars; we Russians paint the soul of space." In Europe, there is a realist tradition, but mixed with a sense of surrealism. Pesek painted realistic lunar landscapes where a flower peeks out from under a craggy lunar rock. In another painting, a staircase climbs a rocky hill and then wanders off into an infinite sky.

Pesek's career exemplifies our culture's slender interface between science, art, and the human conception of the









**Top Left: The Pesek space painting *Symbolism* includes surrealistic elements. Left: *Czech Countryside* demonstrates longing for the artist's native country after he moved to Switzerland. Above: Pesek made 35 paintings in his early 1980s series *The Planet Mars.***

universe and raises questions of what we really know through scientific analysis versus artistic synthesis of knowledge. Scientists tend to publish quantitative assessments of parts of nature; astronomical artists try to present how it might feel to witness a completely alien environment. An example comes from Pesek's work on Saturn's rings. Pesek was one of the first artists to realize that if the rings are made of countless centimeter-scale particles orbiting the planet, then spectacular views could be had by an observer floating among the ring particles, adrift among countless hailstones. In one early painting, he showed Saturn's ring particles as rocky pebbles. When later discoveries revealed they were ice particles, Pesek was asked by *National Geographic* to do a new view, and he created a painting where the viewer floats among irregular, white ice fragments. Art directors like to check authenticity and sometimes scientific consultants are brought in. The consultant in this case was my own doctoral advisor, the pioneering planetary astronomer Gerard P. Kuiper.

I recall at that time Kuiper was enthralled by his own discoveries about the icy bodies crowded into the rings, and he enjoyed exercising his own imagination. In this assignment to help an artist create a view of the rings, Kuiper reasoned that the ring particles would be abrading one another other and would not retain irregular shapes but would grind each other into smoother cylindrical shapes. So Ludek was sent back to repaint the picture. When he finished, a second advisor was brought in. The new advisor said the cylindrical particles were too far-fetched, and that the first painting was more realistic. The experts contradicted each other; *National Geographic* ended up running both paintings. As cynical trial lawyers have proved, for every expert there is an equal and opposite expert. As for the actual ring-particle shape, we still don't know; the careful artist's assessment of the body of scientific opinion may be as valuable, in the long run, as individual (contradictory) expert opinions.

Pesek's reputation has spread among space researchers and has helped to break down the barriers between science and art. Recently, I attended a scientific meeting about Mars at the International Space Science Institute in Bern, Switzerland. There on the walls to greet me were two Ludek Pesek paintings of Mars, depicting a landscape and a martian dust storm.

When I pressed Ludek about his motivations for creative work, his answer was firm and enthusiastic. "I can't live without painting. It's the same as with breathing," he said. "When I get an idea I want it to be realized. And I have enough ideas that I can't paint them all." A

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*William K. Hartmann is an astronomer, painter, and writer; in 1997, his first novel,* Mars Underground, *was published, and he was named the first winner of the Carl Sagan Medal of the American Astronomical Society for science communication. He is a regular contributor to* Astronomy.

# A Century of Comets

*Predicting a comet's brightness is part science and part art; just when a new one will appear is pure guesswork.*

**by Rex Graham**

It's no wonder comets enrapture us. Some are brighter than Venus, more beautiful than the moon, and as fleeting as a summer romance. While this century's best and brightest comets are fading into the distance, comet-hunters around the globe are gazing through eyepieces nightly, hoping to discover a new celestial debutante that one day could bear their names. Every comet is unique. Picking the 20th century's best is subjective, but any list would have to include the Great January Comet of 1910, Halley (both in 1910 and 1986), Arend-Roland (1957), Mrkos (1957), Ikeya-Seki (1965), Bennett (1970), West (1976), Hyakutake (1996), and Hale-Bopp (1997). Shoemaker-Levy 9, the "string of pearls" comet, also delighted us when its 20-plus fragments plopped into Jupiter for seven days in July 1994 like coins dropped into a wishing well.

Comet Hale-Bopp — the last great comet of the 20th century unless another bright one appears in the next five months — rounded the sun on its elliptical orbit and glided across the northern sky in 1997. We can only guess how Hale-Bopp appeared during her previous perihelion, or closest approach to the sun, which was 4,210 years ago — shortly before ancient Chinese astronomers first began recording "broom stars."

**Comet Hale-Bopp's appearance in 1997 wrote a spectacular conclusion to 100 years of great comets.** John Wellbeloved

Comet LINEAR (C/1999 S4) should become the brightest comet of 2000 when it peaks at about 4th magnitude in July. Although its expected naked-eye appearance will make for a nice display, LINEAR certainly won't reach the level of greatness that Hale-Bopp did in 1997.

"On average, we get a good comet every seven or eight years, but we may go 20 or even 40 years without anything noteworthy," says Brian Marsden, associate director at the Harvard-Smithsonian Center for Astrophysics and director of the International Astronomical Union's Central Bureau for Astronomical Telegrams. "In 1910 we had two nice comets in the Northern Hemisphere, but then we had nothing until Arend-Roland came along 47 years later. That's the way it is with random events."

Marsden is one of a small group of planetary scientists that keeps track of the precise movements of hundreds of comets. Using computer software, they enter a comet's sky positions and deduce its trajectory. They do this by calculating the gravitational effects of the sun and planets on each comet as well as the nongravitational effects from escaping gases, which spew from cracks in a comet's surface like rocket thrusters. Finally, they estimate a comet's maximum brightness, the trickiest part. The process is part science, part art, and part guesswork. In 1973–74 Comet Kohoutek appeared surprisingly luminous while far from the sun, but it failed to brighten nearly as much as many astronomers had predicted.

## Dirty Snowballs

Astronomers have determined the orbits of about 1,100 individual comets since 240 B.C. Ancient Chinese, Babylonian, and other civilizations recorded several hundred more presumed comets. Ground-based telescopes have photographed an additional 275 quiescent comets that orbit the sun beyond Neptune in the Kuiper Belt, a region that extends out to roughly 50 times the sun-Earth distance. (The sun-Earth distance, approximately 93 million miles, is 1 astronomical unit, or AU.) Comets located beyond about 50 AU from the sun would be hard to detect because most tend to be less than a few miles in diameter and as black as the darkest velvet. Comets tend to produce a coma, a bright visible head, only when their orbits bring them within about 3 AU of the sun.

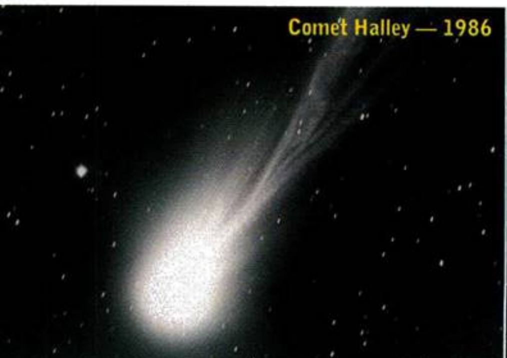
Each comet's black organic crust covers an icy interior of frozen water and gases, silicate dust, and trace amounts of all the elements present when the solar system originally formed. In 1950 astronomer Fred L. Whipple coined the phrase "dirty snowball" to describe them. Whipple's description still fits.

Because new comets appear in Earth's neighborhood so frequently, the solar system must have lots of unseen comets — though nobody knows how many or precisely where they are. Since comets are inactive and too small to be observed beyond about 50 AU, comet research relies heavily on computer modelers such as Harold Levison, an astronomer at the Southwest Research Institute in Boulder, Colorado. "With comets, all we see is the tip of the iceberg," says Levison. "From the tip of the iceberg, we try to estimate how big the iceberg is. It's a tough problem."

Nobody knows how many comets formed in the infant solar system some 4.5 billion years ago: estimates range as high as 100 trillion objects. While that number is a guess, Levison and other theorists say the total mass of all the primordial comets is more predictable — that mass might have been equivalent to about 60 to 70 Earths. These original comets aligned themselves in a disk that began near the present location of Jupiter and extended outward possibly several thousand AU. Only 1 to 5 percent of the original comets may remain in the solar system today. Why? They were incompatible with large planets.

Levison and a group of his colleagues think that after Jupiter and Saturn formed, their powerful gravity (particularly that of the more massive Jupiter) ejected a vast number of nearby comets completely out of the solar system. Computer modeling by Philip J. Armitage of the Canadian Institute for Theoretical Physics and Brad Hansen, a Princeton University astronomer, show that the formation of Jupiter and Saturn could have triggered the formation of the solar system's other two gas giants — Uranus and Neptune. According to these simulations, all four planets formed within a narrow gas- and comet-rich ring 5 to 10 AU from the sun. In theory, Uranus and Neptune drifted outward to their present locations at 19 and 30 AU, respectively. And

Left, top and bottom: Lick Observatory; right: Bill and Sally Fletcher



Comet Halley — 1986

Comet Bennett — 1970

Comet Hale-Bopp — 1997

Comet West — 1976

Comet Halley — 1910

Comet Arend-Roland — 1957

Left: Ronald Royer; right, top: Lowell Observatory; right, bottom: Carnegie Observatories

while they drifted outward, the planets ejected comets in their paths out to what's called the scatter disk, says Levison.

The outer, unperturbed part of this original disk of comets — the Kuiper Belt — remains today. The region of the Kuiper Belt between Neptune's orbit and about 50 AU contains perhaps a billion comets larger than 0.6 mile (1 km) in diameter with a total mass of less than one Earth. Astronomers think that the Kuiper Belt and the scattered disk of comets are the primary sources of the so-called ecliptic comets. These comets orbit the sun on paths that deviate relatively little from the plane of the solar system (the ecliptic) and move in the same direction as the planets and asteroids. Most short-period comets are ecliptic comets.

Comets in the outer part of the scattered disk have unstable orbits, prone to perturbations from outside the solar system. The orbits of comets scattered out at least 6,000 AU from the sun became elongated and randomized. Eventually these unstable comets formed the Oort Cloud, which extends from about 6,000 AU to 200,000 AU, the edge of the solar system.

Passing stars, clouds of gas, and gravitational tugs from the massive disk of the Milky Way Galaxy occasionally jostle Oort Cloud comets. If sufficiently prodded, these comets can careen directly toward the inner solar system as nonecliptic, or long-period, comets. To complicate matters, some Oort Cloud comets, such as Halley, become short-period comets when perturbed by the gravity of the planets. Halley retains its retrograde orbit, moving against the flow of planet and asteroid traffic, but its orbital period has shrunk from possibly a million years to only 76 years.

## Fiery Endings

Comet 2P/Encke, which has the shortest period of any known comet — 3.3 years — will reach its 58th observed perihelion passage on September 9 at 9th magnitude. Eventually, Encke will look like an asteroid. Indeed, astronomers discovered two objects last year — 1999 LD31 and LE31 — that appear to be the rocky remains of comets that have lost their volatile gases. These two unusual objects move around the sun in retrograde orbits, as do about 96 percent of comets that have been in the Oort Cloud.

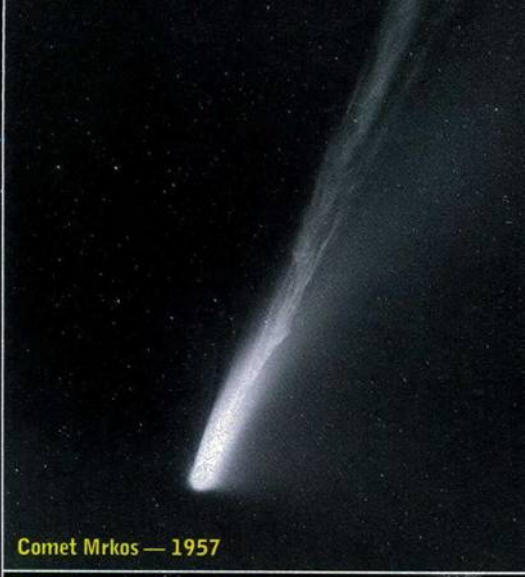
Like Encke, all visible comets are in their death throes. Some perish suddenly by colliding with the sun or a planet (like Shoemaker-Levy 9) or by breaking into pieces as they near either. Some comets die slowly, losing part of their mass from evaporation during each close encounter with the sun and its powerful radiation. It's this erosion that creates a comet's coma and tail. Solar erosion can also lead to an equally impressive sky show: a meteor shower.

The source of the annual Leonid meteor shower, which can be spectacular every 33 years or so around November 17, is 55P/Tempel-Tuttle. This comet was discovered on December 19, 1865, by Ernst Wilhelm Liebrecht Tempel and independently 18 days later by Horace Parnell Tuttle. Comet debris, ejected in high-speed jets from a short-period comet, can spread around the length of the orbit, "closing the ring in a few tens of revolutions," Canadian astrophysicist Bruce McIntosh writes in *Comets in the Post-Halley Era*. Ten annual meteor showers have been linked to such debris spreading, including the Eta Aquarids of May and the Orionids of October from Halley, the August Perseids from Comet 109P/Swift-Tuttle, and the November Taurids from Encke.

The sun-orbiting Ulysses spacecraft serendipitously discovered just how far the material shed by a comet can go. On May 1, 1996, the spacecraft, which was then monitoring the steady wind of charged particles from the sun, suddenly went haywire. Astronomers later realized that the spacecraft had passed through the ionized vapor tail of Hyakutake, which on that day was 350 million miles (570 million km) away. The discovery, reported in the April 6, 2000, issue of *Nature*, broke the longest-tail record set by what some astronomers consider the greatest comet ever seen — the great comet of 1843. That 19th-century comet came within 80,000 miles (130,000 km) of the sun's surface and was 100 times brighter than Venus. The comet's tail was estimated to be 200 million miles (320 million km) long.

In just six years, scientists will get their first close-up look at what makes up a comet's tail. The Stardust spacecraft is scheduled to return to Earth in 2006 after a seven-year, round-trip flight to Comet 81P/Wild 2. The spacecraft will

Comet Hyakutake — 1996



Comet Mrkos — 1957

Comet Ikeya-Seki — 1965

Left: Leo Enright; right, top: Carnegie Observatories; right, bottom: Lick Observatory

collect dust particles from the comet's tail. Wild 2 demonstrates a route that short-period comets can take on their way to oblivion. The elliptical orbits of some short-period comets can shrink progressively, constricting from Neptune to Uranus, Saturn, and finally Jupiter. A steady supply of incoming comets takes the route inward — with individual comets sometimes reversing a step before continuing the inward march. Marsden and Japanese astronomer Syuichi Nakano discovered that prior to its 1974 close encounter with Jupiter, Wild 2 had an orbital period of 40 years or longer and a perihelion of 4.9 AU. During that fateful perihelion, Jupiter perturbed Wild 2 and tossed it into a smaller orbit, one with a period of only 6 years and perihelion of 1.5 AU.

Long-period comets can be jostled, too. The aphelion of Comet West, for example, was only about 1,000 AU, but its 1976 trip around the sun sent it way out to the Oort Cloud. The orbits of long-period comets can contract as well. Jupiter's gravitational tug shortened Hale-Bopp's orbital period from 4,210 years to roughly 2,500 years after its 1997 trip through the inner solar system.

Dutch astronomer Jan Oort in 1950 computed the aphelion distances of a group of long-period comets and found that they come from all directions from a distant, spherical cloud of comets that now bears Oort's name. Many astronomers have since reinforced and refined Oort's theory and helped figure out ways to get comets from there to here. For example, the occasional passage of vast invisible clouds of interstellar gas could also jostle comets from the Oort Cloud. The motion of the solar system above and below the plane of the Milky Way Galaxy is thought to trigger sudden influxes of comets every 30 million years or so. "On our time scale we don't notice anything," says Donald Yeomans, manager of NASA's Near-Earth Objects Program office.

Comets are credited with delivering a significant amount of water and organic molecules to Earth during and after its formation some 4.5 billion years ago. "One of the most important outstanding questions about comets is the degree to which they contributed to life on Earth," says Whipple, 93, an emeritus astronomer and former director of the Smithsonian Institution Astrophysical Observatory. "In fact, comets remain a real danger: There is even a chance — a remote chance — that during the next 100 years a big one will hit us." **A**

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*Rex Graham is a senior editor of* Astronomy.

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|---|---|
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Mention Ad A-7

# sky Show

august

## Summer's Best: Star Clouds, Star Parties, and Shooting Stars.

by Martin Ratcliffe and Alister Ling

August is the most popular time of year to observe. Several meteor showers send speedy flares across the sky, most notably the famous Perseids. The backdrop to this action is the spectacular summer Milky Way, arching from our galaxy's central bulge at the southern horizon through the dark Great Rift lying overhead.

Now is the time to attend a star party to view the sky's riches in their prime. Star parties are annual gatherings of dozens or hundreds of amateurs. Listen to some astronomy talks, check out photos and equipment, and look through large telescopes. See page 118 for a listing of the ones nearest you, or visit Astronomy.com.

The fine annual Perseid meteor shower peaks on August 11–12. Despite the bright moon, it's well worth the effort to head out to a dark site and take sleeping bags and drinks. Bright and swift shooting stars every few minutes are sure to elicit "oohs" and "aahs" from the whole family.

**The Perseid meteor shower is a highlight of August observing.** Jim Pryal

Even if your camping trip is on a different weekend, keep an eye skyward because a few minor showers will grace the starry vault.

The brightest stars of summer, Deneb overhead, Vega to its west, and Altair below to the south, form the Summer Triangle. They frame the Milky Way at the zenith as it arches across a dark sky. Use binoculars to slowly scan along its length, and you'll see bright clumps of star clusters and plenty of dark lanes and patches containing the gas and dust that are the building blocks of future stellar nurseries. (See page 69.)

**The summer Milky Way contains dozens of star clusters and nebulae.** Jerry Schad

Stay up late to observe the gas giant planets Jupiter and Saturn. Rising near midnight, the pair swapped places since we last saw them in spring. On August 21, the moon forms a nice line with Saturn and Jupiter. The moon then slides below Saturn on the next night and below Jupiter on the 23rd. Saturn's rings have tilted 24° toward us, almost as much as they can, providing an exceptional 3-D view. Watch for changes in the Jovian cloud tops. Will the Great Red Spot darken this year?

Both Jupiter and Saturn carry with them a large entourage of satellites. A number of these moons appear in modest telescopes or even binoculars. Use the chart on page 65 to track some of the largest moons.

# 2000
# August

2 The moon passes 0.008° south of Pallas, 1 P.M. EDT

3 Asteroid Metis is at opposition, 6 A.M. EDT
Mercury passes 7° south of Pollux, 6 P.M. EDT

6 Venus passes 1.1° north of Regulus, 3 A.M. EDT
First quarter moon is at 9:02 P.M. EDT

10 Mercury passes 0.09° south of Mars, 9 A.M. EDT

11 Uranus is at opposition, 1 A.M. EDT (page 70)
The moon is at apogee (252,060 miles from Earth), 6:25 P.M. EDT

12 Asteroid Juno is at opposition, 4 A.M. EDT
Perseid meteor shower peaks (page 72)

13 The moon passes 1.1° south of Neptune, 1 P.M. EDT

14 The moon passes 1.4° south of Uranus, 4 P.M. EDT

15 Full moon is at 1:13 A.M. EDT

21 Mercury is in superior conjunction, 9 P.M. EDT

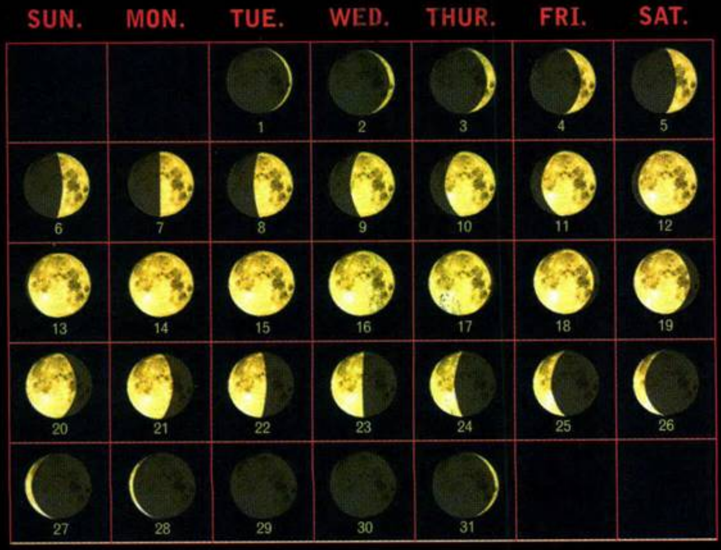
22 Last quarter moon is at 2:51 P.M. EDT
The moon passes 2° south of Saturn, 3 P.M. EDT

23 The moon passes 3° south of Jupiter, 6 A.M. EDT

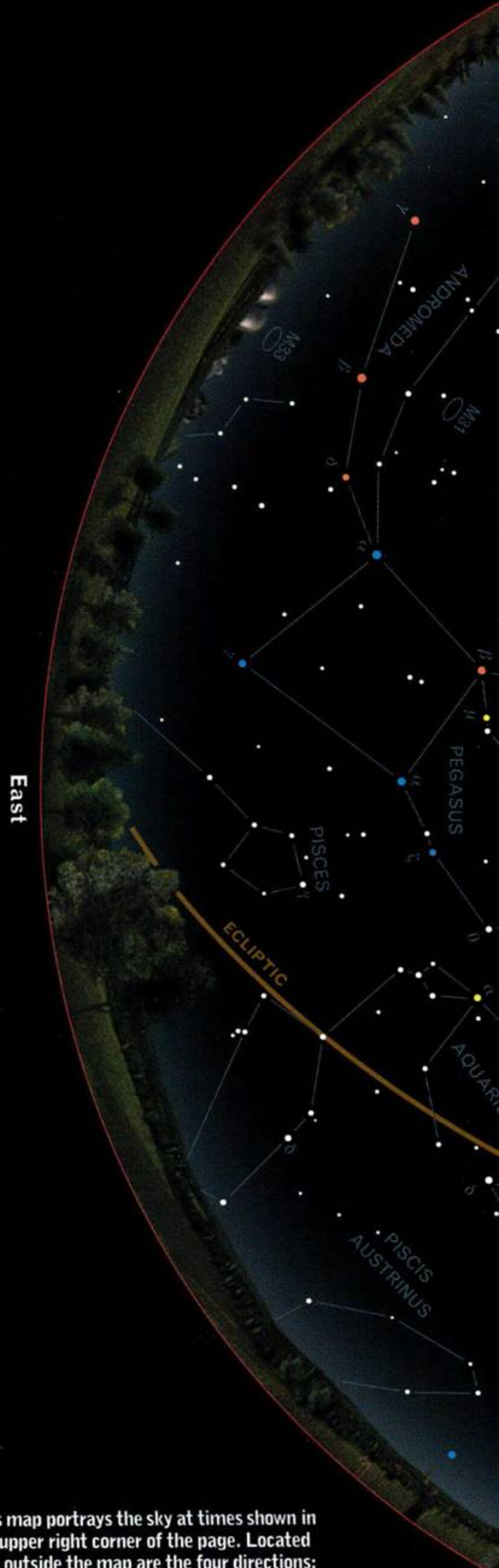
27 The moon is at perigee (224,878 miles from Earth), 9:59 A.M. EDT
The moon passes 0.9° north of Mars, 11 P.M. EDT

29 New moon is at 6:19 A.M. EDT

30 The moon passes 4° north of Venus, 7 P.M. EDT



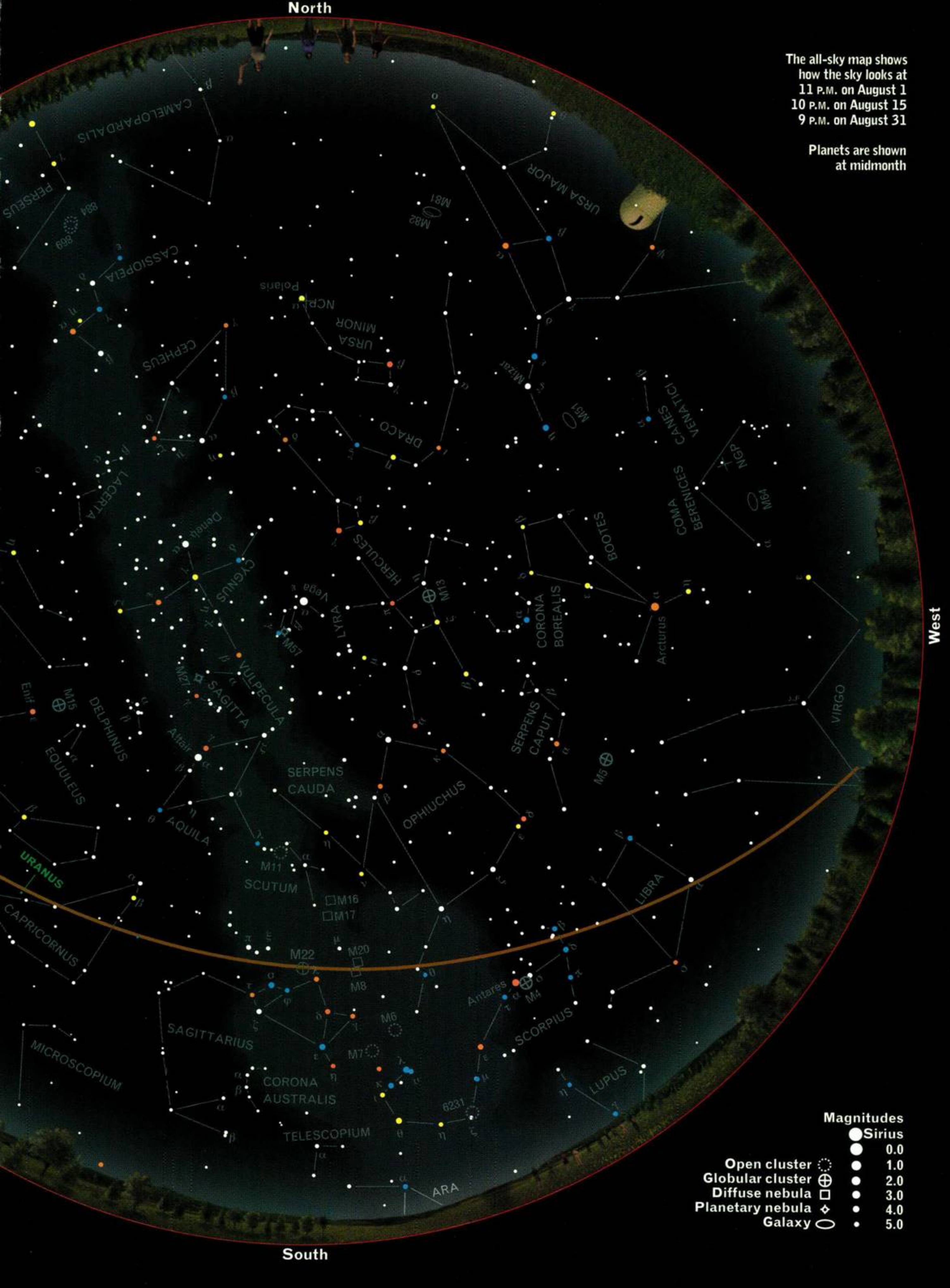
| SUN. | MON. | TUE. | WED. | THUR. | FRI. | SAT. |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | 31 | | |



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above *your horizon, hold the map overhead* and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

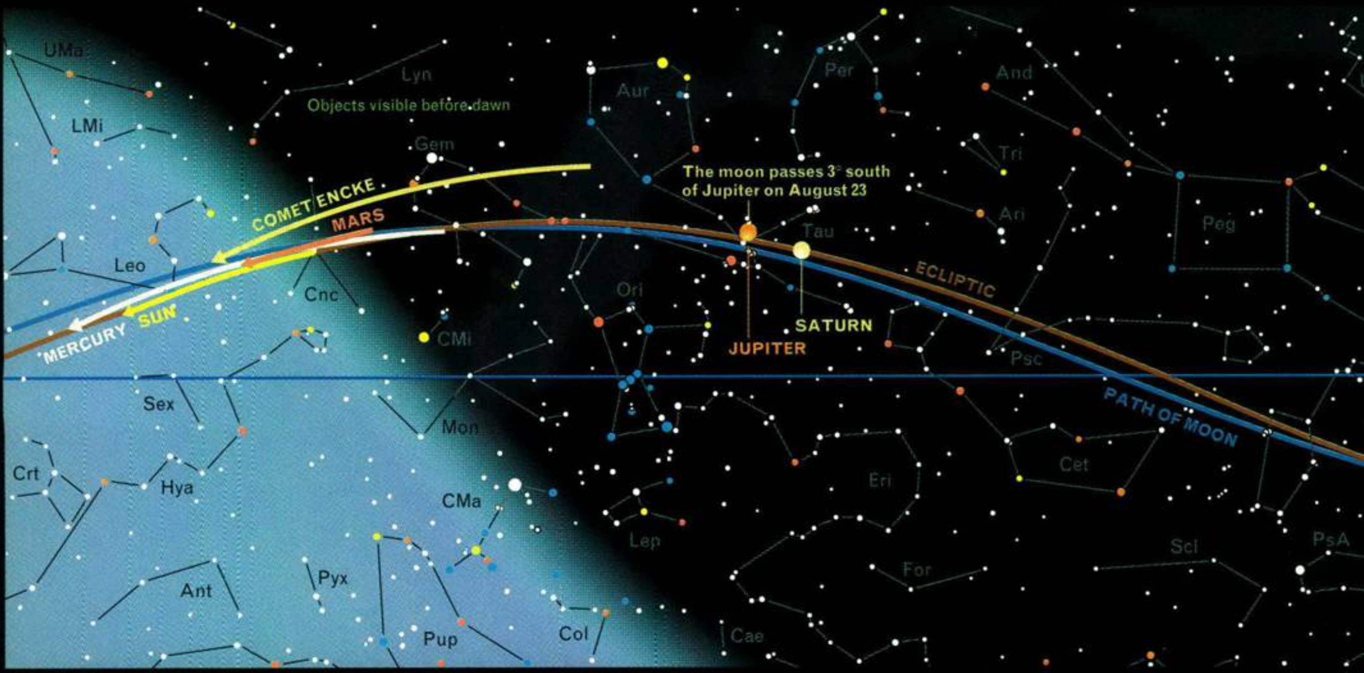
The all-sky map shows
how the sky looks at
11 P.M. on August 1
10 P.M. on August 15
9 P.M. on August 31

Planets are shown
at midmonth

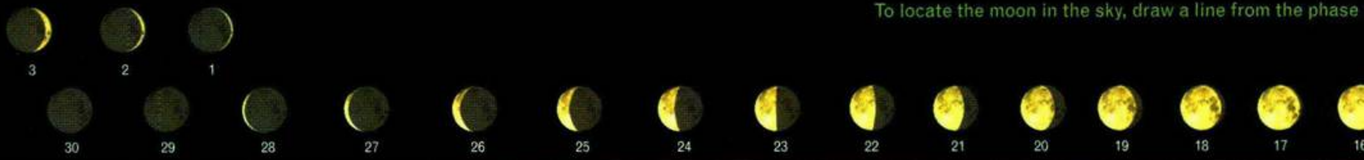

North
South
West
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
CEPHEUS
LACERTA
URSA MAJOR
M81
M82
Polaris
NCP
URSA MINOR
DRACO
Mizar
M51
CANES VENATICI
NGP
COMA BERENICES
M64
BOOTES
Arcturus
CORONA BOREALIS
HERCULES
M13
Vega
LYRA
M57
CYGNUS
Deneb
VULPECULA
M27
SAGITTA
Altair
DELPHINUS
Enif
M15
EQUULEUS
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
VIRGO
LIBRA
URANUS
CAPRICORNUS
M11
SCUTUM
M16
M17
M22
M20
M8
M6
M7
M4
Antares
SCORPIUS
SAGITTARIUS
MICROSCOPIUM
CORONA AUSTRALIS
TELESCOPIUM
6231
LUPUS
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

# Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system object


UMa
Lyn
LMi
Objects visible before dawn
Gem
Aur
Per
And
Tri
Ari
Peg
The moon passes 3° south of Jupiter on August 23
Tau
COMET ENCKE
MARS
Leo
Cnc
SUN
MERCURY
Ori
ECLIPTIC
SATURN
JUPITER
CMi
Psc
Sex
Mon
PATH OF MOON
Crt
Hya
CMa
Eri
Cet
Lep
Scl
PsA
Ant
Pyx
For
Pup
Col
Cae

To locate the moon in the sky, draw a line from the phase


3
2
1
30
29
28
27
26
25
24
23
22
21
20
19
18
17
1

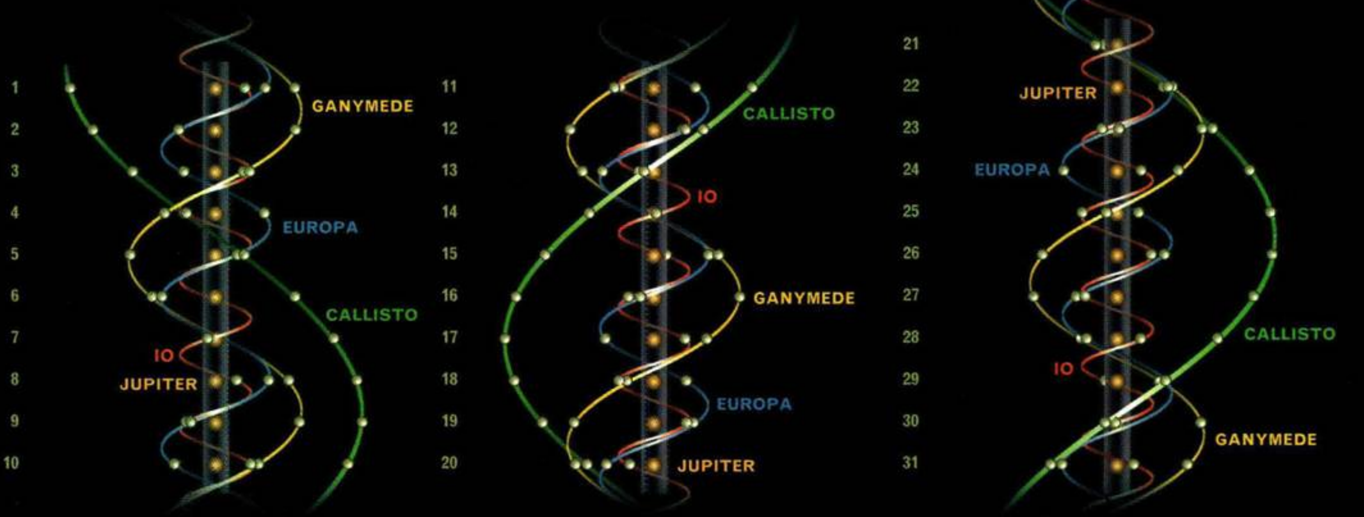
10"

S
W E
N

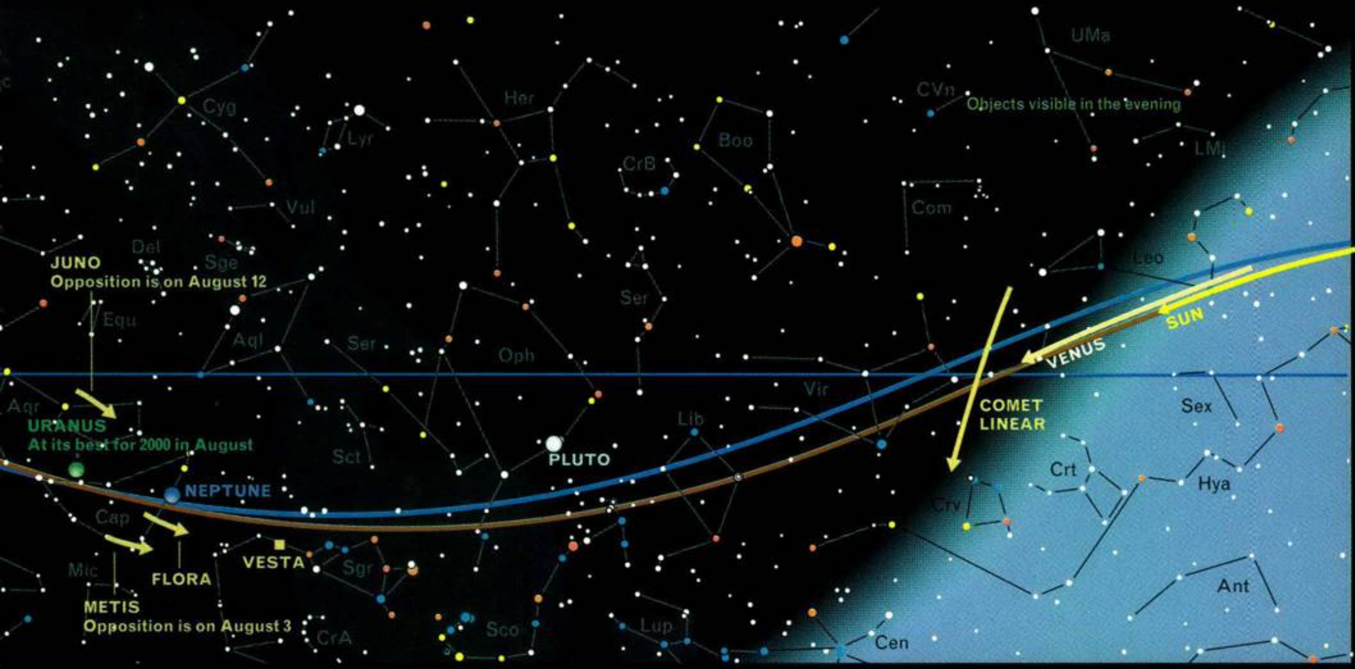
| PLANETS | MERCURY | MERCURY | VENUS | MARS | JUPI |
|---|---|---|---|---|---|
| Date | August 1 | August 15 | August 15 | August 31 | Augu |
| Magnitude | –0.4 | –1.6 | –3.9 | 1.8 | –2 |
| Angular Size | 6.8" | 5.2" | 10.3" | 3.6" | 38. |
| Illumination | 54% | 95% | 95% | 99% | 99 |
| Distance (AU) from Earth | 0.988 | 1.290 | 1.615 | 2.570 | 5.1 |
| Distance (AU) from Sun | 0.330 | 0.316 | 0.720 | 1.646 | 5.0 |
| Right Ascension (2000.0) | 7h26.8m | 9h11.8m | 10h48.9m | 9h28.1m | 4h25 |
| Declination (2000.0) | 21°00' | 17°47' | 9°05' | 16°10' | 20° |

# Jupiter's Moons

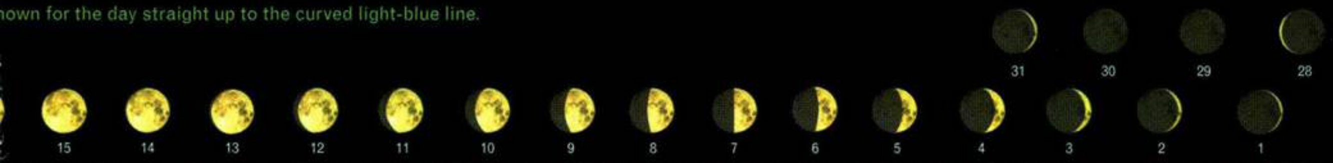
Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.



during the month.


UMa
CVn
Objects visible in the evening
LMi
Cyg
Her
Lyr
Boo
CrB
Vul
Com
Del
Sge
JUNO
Opposition is on August 12
Leo
Equ
Ser
SUN
Aql
Ser
Oph
VENUS
Vir
Aqr
COMET
LINEAR
Sex
URANUS
At its best for 2000 in August
Lib
PLUTO
Sct
Crt
Hya
NEPTUNE
Crv
Cap
VESTA
Sgr
Mic
FLORA
Ant
METIS
Opposition is on August 3
Sco
Lup
CrA
Cen

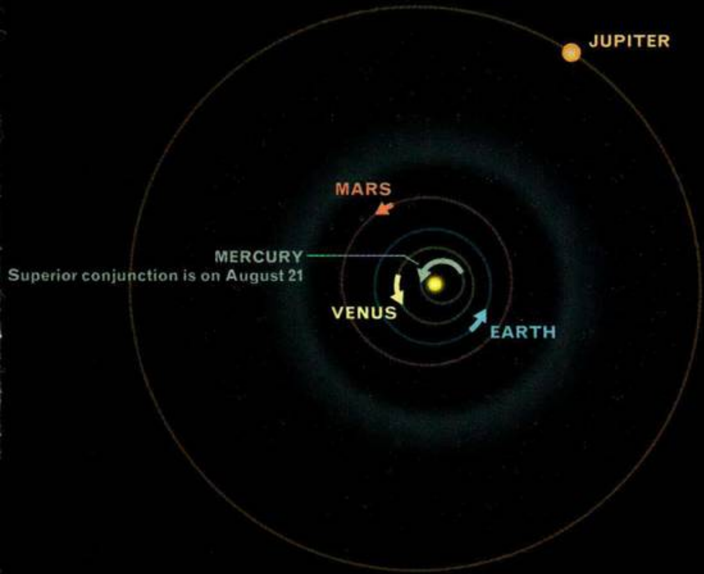
own for the day straight up to the curved light-blue line.

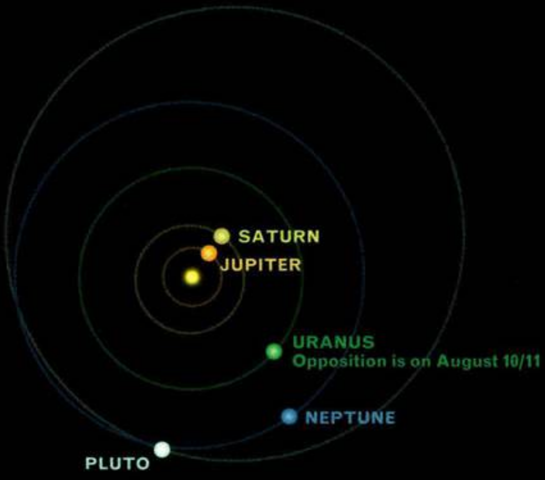

31
30
29
28
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

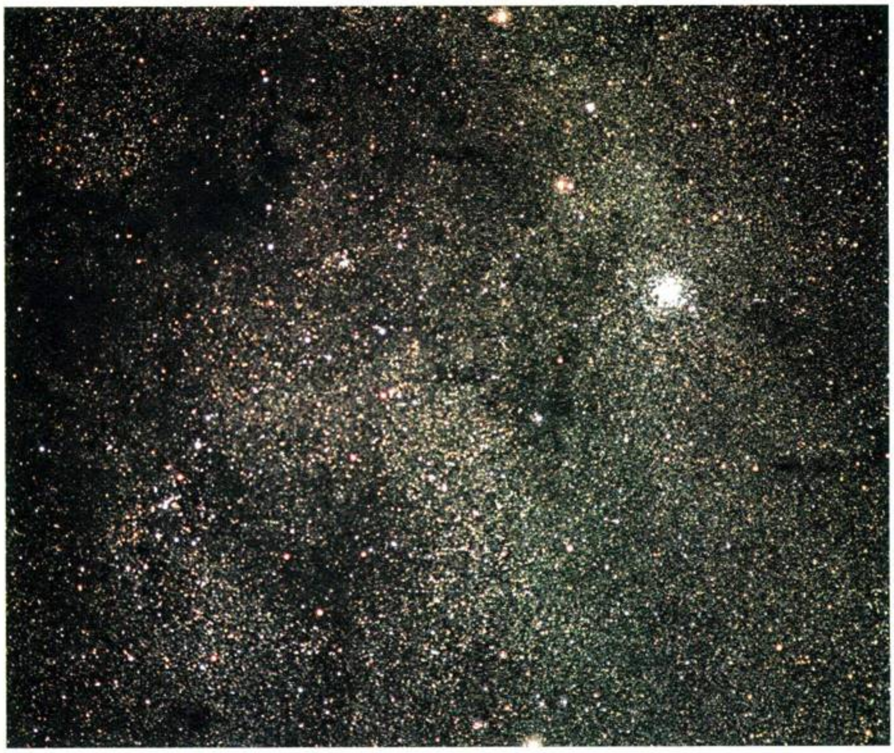
| ER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|
| t 15 | August 15 | August 15 | August 15 | August 15 |
|  | 0.2 | 5.7 | 7.8 | 13.8 |
|  | 18.0" | 3.7" | 2.3" | 0.1" |
|  | 100% | 100% | 100% | 100% |
|  | 9.220 | 18.935 | 29.147 | 29.975 |
|  | 9.138 | 19.945 | 30.113 | 30.293 |
| m | 3h54.2m | 21h25.4m | 20h27.9m | 16h40.6m |
|  | 18°07' | –15°56' | –18°53' | –11°09' |

## The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


JUPITER
MARS
MERCURY
Superior conjunction is on August 21
VENUS
EARTH


SATURN
JUPITER
URANUS
Opposition is on August 10/11
NEPTUNE
PLUTO



**The dark nebulae on the left are B113 and B110. M11 is the bright cluster at right.** James Foster

### The Battle between Light and Darkness

The Scutum star cloud is one of summer sky's finest tourist attractions. Its resplendent crown jewel is M11, the Wild Duck Cluster. (See the map on pages 67–68.) Much observing activity awaits in this area, including finding a bright variable star and tracking an asteroid as it passes a planetary nebula. Outside of urban sites you can explore several prominent dark regions discovered by Edward Emerson Barnard in the late 1800s.

The 19th-century British amateur astronomer William Henry Smyth christened the Wild Duck Cluster. At first glance you see a bright star appearing to lead a flock of fainter ones in a distinct V-shape. Increase the power and the cluster breaks up into a mazelike pattern of dark lanes threading between curious clumps of stars.

Within the same finder or binocular field of view as M11 is the irregular variable star R Scuti. Look for a squashed box, or trapezium, of four stars just to the northwest, or upper right. R Scuti is the farthest one of the four from M11. At its brightest, this orange star glows at magnitude 4.5, in contrast to its redder hue when at its 9th-magnitude minimum.

Star cloud are beautiful, brighter patches in the sky where high concentrations of stars can be found. We see the richest ones when we look along a spiral arm of the Milky Way. Like other star clouds, the one in Scutum has dark lanes and blobs surrounding it, created by obscuring dust and gas. With binoculars in a rural location, you can follow the dark Great Rift past the right-hand edge of the Scutum star cloud.

Barnard photographed and cataloged more than 350 dark nebulae in the Milky Way. A number of these are frequently featured in stunning photographs of crowded starfields. Some are very easy to see with the naked eye or binoculars, while others are notoriously difficult. (See "Come to the Dark Side," May 2000.)

B111 is, in Barnard's words, "a beautiful region of dark structures." It spans an impressive 2°, forming a convex, or C-shaped arc, a perfect size for binoculars sitings. If you're at a star party, knock your socks off with a view of this area through a borrowed pair of extra-large binoculars.

You can easily spend an hour or two mesmerized by the intricate beauty of the star clouds and dark nebulae in the Scutum star cloud. One of the most subtle, yet sublime, dark nebulae is the long and narrow B318. Its razor-thin line requires the highest contrast nights, and even then you'll only see segments. It lies just to the right of the Wild Duck Cluster in the above picture, extending slightly below it and continuing straight upward to the top of the image.

The planetary nebula NGC 6751 provides a challenge for a 10-inch scope from under the light dome of a city. At half the apparent size of Jupiter, this 20"-diameter gray oval lies just 1.1° south of Aquila's tail star Lambda (λ) Aquilae. Use a nebular filter and a dark cloth over your head to cut out the light pollution and enhance the feeble 11.9-magnitude glow.

The 10th-magnitude asteroid 80 Sappho slides through the field of NGC 6751 early in the month. On the evening of the 3rd, Sappho lies 20' to the planetary's east, and by the next night, it's a mere 5' south.

**The planetary nebula NGC 6751 makes for a good challenge in medium scopes.** Jack Marling

# sky Show

**Venus** is playing catch-up with Earth. Although it won't win the race this month, the second planet eventually will, thanks to Kepler's laws of planetary motion. Kepler's third law tells us that the smaller the orbit's size the faster the period of orbit around the sun. Venus performs its cycle around our star every 224.7 days, whereas Earth takes 365.25 days.

The evening visibility of Venus remains poor, however, lingering near the western horizon shortly after sunset. Telescopes that can catch a view of the shimmering globe will notice a slightly shrinking gibbous phase — during August the illumination diminishes from 97 percent to 93 percent. Try tracking the evening star's phase throughout this year — even by December the globe of Venus will remain more than 60-percent illuminated. On August 5 careful viewers may catch Venus passing a little over 1° north of Regulus, the 1st-magnitude star in Leo the Lion. Don't wait too long after sunset because Venus sets less than an hour after the sun. You'll need binoculars to spot Regulus in the bright summer evening sky.

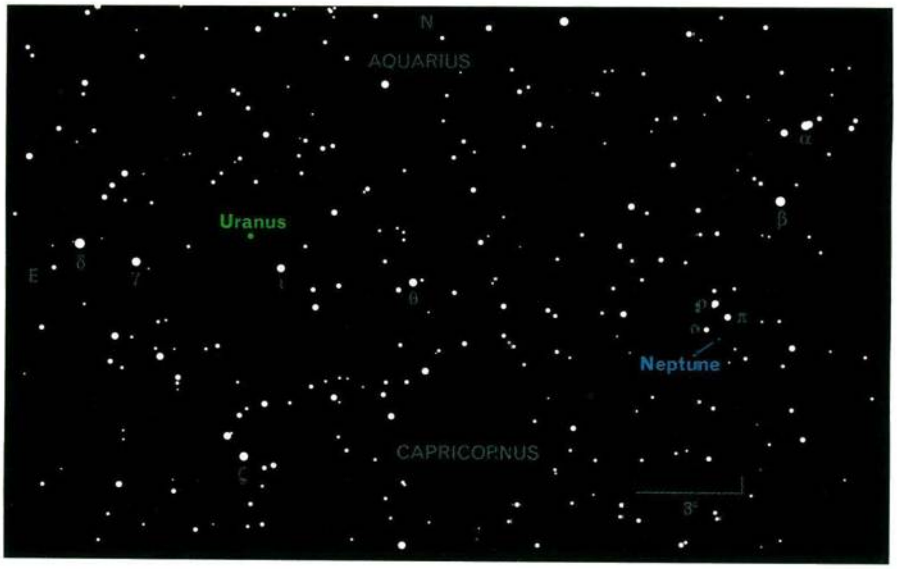
**Neptune** reached opposition in July and begins August lying very near the magnitude 6.7 star Omicron (ο) Capricorni. Omicron lies at the apex of a small triangle formed with two brighter stars, Pi (π) and Rho (ρ) Capricorni. After passing within 10' of Omicron in late July, Neptune begins to move away, a motion that is clearly recognizable in the first few days of the month. Neptune's dim magnitude of 7.8 does make it a challenge for handheld binoculars, and you'll increase your chances of success by mounting the instrument on a sturdy tripod.

**Uranus**, the solar system's seventh planet from the sun, reaches opposition on August 11. Being opposite the sun in the sky indicates that Uranus lies due south at midnight. Opposition is always the best time to view any planet since it's at its closest to Earth for the whole year. Uranus is so distant, however, that light takes 157 minutes to reach us. In a dark sky, Uranus, shining at magnitude 5.7, can be viewed by the naked eye, although this feat generally requires an experienced observer. For the rest of us, binoculars are useful, though a telescope will ensure the identification of the right object. At sufficiently high power, a scope will reveal the tiny disk that spans less than 4". You can find Uranus moving gradually closer to magnitude 4.3 Iota (ι) Capricorni, near the eastern edge of Capricornus. Toward the end of August, Uranus lies less than 1° north of Iota, in the same low-power field of view through a telescope.

The constellation Ophiuchus the Serpent-bearer has been bearing an extra item these past months. **Pluto** lies within a degree of Zeta (ζ) Ophiuchi during August. Try for the clearest, most transparent and moonless night to find the magnitude 13.8 planet. At least an 8-inch scope should be used, along with an accurate star chart that shows stars down to 14th magnitude. Pluto's path reverts to direct eastward motion after its year 2000 retrograde loop. Next year's opposition takes place in a richer starfield, so use this year as an easier opportunity to catch a glimpse of Pluto.

**Bright Venus is often mistaken as an airplane when it lies close to the horizon.** Wallace Baldwin

**Jupiter** and **Saturn** make up the spectacular pairing that rises shortly after midnight in the east. Jupiter moves close to the Hyades star cluster and contrasts beautifully with the ruddy orange color of Aldebaran, Taurus's brightest star. By August 15 Jupiter stands within 2° of Epsilon (ε) Tauri, the tip of the western arm of the "V" of the Hyades. Saturn is the bright "star" south of the Pleiades, or Seven Sisters. The last quarter moon joins the grouping on August 21, stretching out over 15° as they rise before midnight. The following night the moon sits squarely among the V of the Hyades and lies less than 4° south of Jupiter.

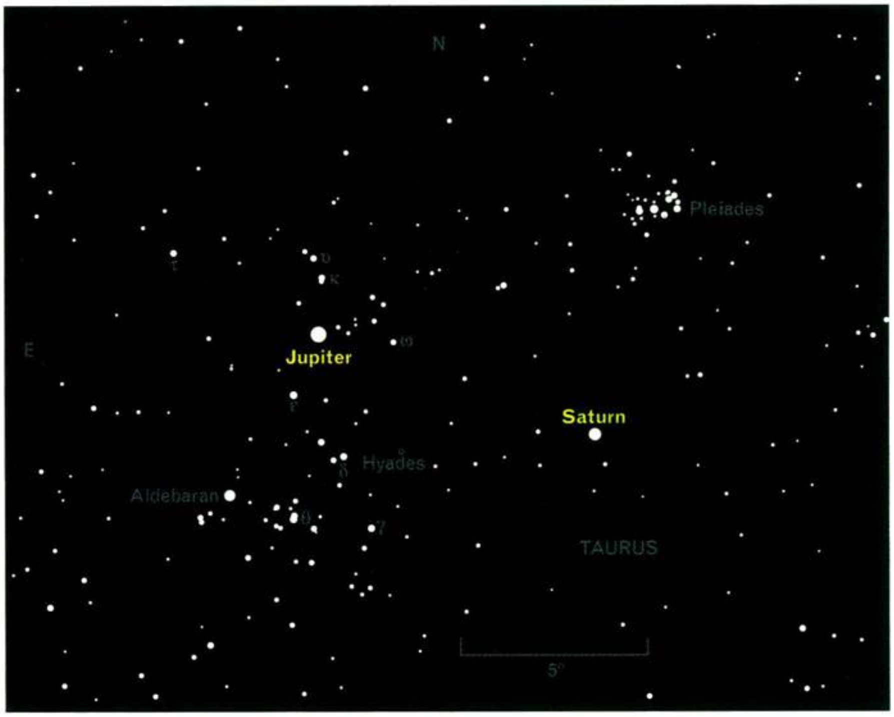


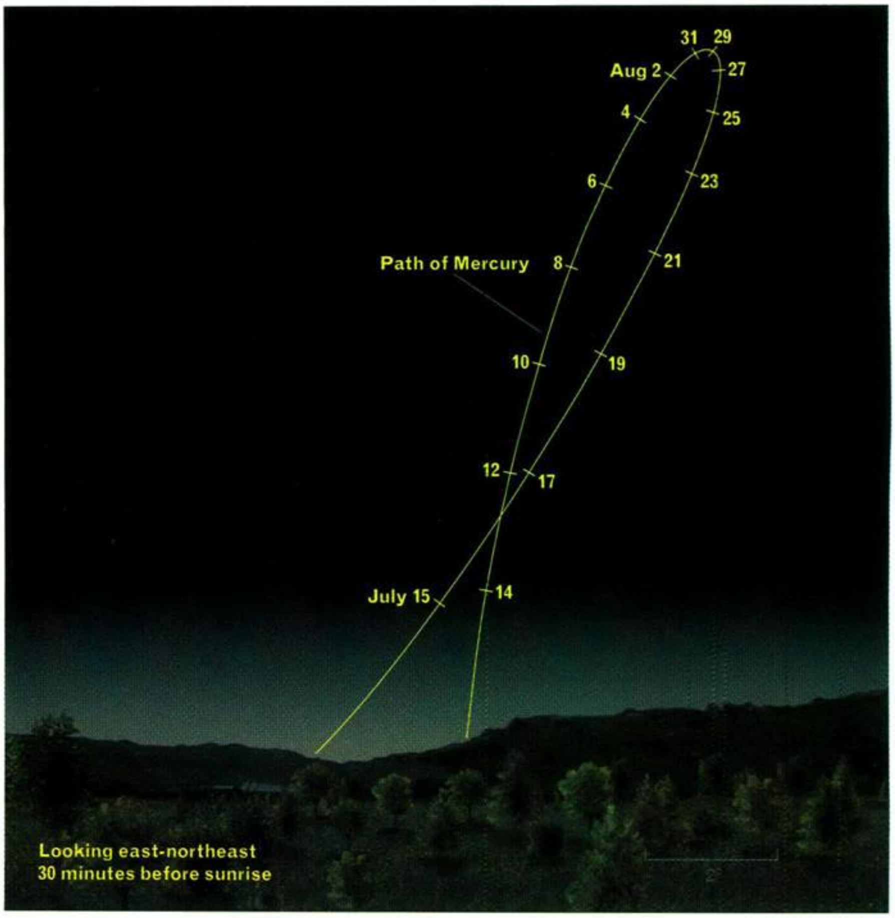
Once the moon moves away, try photographing this region of sky for some spectacular conjunction images.

Jupiter and Saturn are at their highest above the horizon near dawn — the best time during August to view them telescopically. Saturn, which rises first, shines at magnitude 0.2 and reaches quadrature — 90° west of the sun — on August 23. This relative positioning makes the shadow of the planet on the rings most evident. Saturn's disk subtends 18", while the long axis of the rings stretches 40". Currently we can view the southern face of the rings because the southern pole of Saturn tilts toward us by 24°. Saturn's moons are also on fine display, Titan being the easiest to identify, but a 6-inch scope will show a few others. You can track Titan and Iapetus this month by using the locator map on page 72.

Jupiter's globe appears three times the size of Saturn's disk as seen from Earth, though in reality it is only 18 percent larger. The larger size is due to Jupiter's relative closeness. Saturn currently lies 9 astronomical units from Earth (1 AU equals 93 million miles); Jupiter is only 5 AU away during August. Jupiter brightens to magnitude –2.3, its brilliance outshining everything in the sky near it except the moon. By opposition date in November, these distances will have shrunk to 8 and 4 AU, respectively. As Jupiter approaches its opposition, the disk will become apparently larger and details in its atmosphere will be more readily visible. Yet Jupiter always has something to offer curious observers — fine detail in addition to the dark equatorial belts that are so obvious in the smallest of scopes. Jupiter is also approaching quadrature — a good time to watch various satellite phenomena (see the chart on page 72).

**Mercury** remains visible before sunrise for the first few days of August but descends rapidly into the solar murk. It brightens to magnitude –1.2 on August 9, at its perihelion (closest orbital point to the sun), but gets harder to see with any obstructions near the eastern horizon. As a curiosity, Mercury passes 0.1° south of **Mars** on August 10.





Looking east-northeast
30 minutes before sunrise

# Meteors and Moons

## Jovian Events

| DATE | TIME (A.M. EDT) | MOON | EVENT |
|---|---|---|---|
| Aug. 7 | 1:43 | Ganymede | OccD |
| | 2:01 | Io | ShadE |
| | 3:16 | Io | TranE |
| | 3:36 | Ganymede | OccR |
| | 3:38 | Europa | OccR |
| Aug. 14 | 2:26 | Ganymede | EclR |
| | 3:04 | Io | TranI |
| | 3:40 | Europa | EclR |
| | 3:44 | Europa | OccD |
| | 3:55 | Io | ShadE |
| | 5:12 | Io | TranE |
| | 5:55 | Ganymede | OccD |
| | 6:17 | Europa | OccR |
| Aug. 21 | 3:40 | Io | ShadI |
| | 3:41 | Europa | EclD |
| | 4:29 | Ganymede | EclD |
| | 4:59 | Io | TranI |
| | 5:48 | Io | ShadE |
| | 6:14 | Europa | EclR |
| | 6:21 | Europa | OccD |
| | 6:26 | Ganymede | EclR |
| | 7:08 | Io | TranE |
| Aug. 30 | 12:02 | Io | ShadI |
| | 1:00 | Europa | ShadI |
| | 1:22 | Io | TranI |
| | 2:10 | Io | ShadE |
| | 3:30 | Io | TranE |
| | 3:34 | Europa | ShadE |
| | 3:47 | Europa | TranI |
| | 6:20 | Europa | TranE |

Occ = Occultation; Shad = Shadow Transit; Tran = Transit; Ecl = Eclipse; D = Disappearance; R = Reappearance; I = Ingress; E = Egress

### The Solar System's Satellites

With Jupiter near quadrature (in a 90° angular separation from the sun, or elongation) the Galilean moons can be seen clear of the limb of Jupiter while their shadows transit the visible face of the planet. In addition, the moons pass behind and into the shadow of Jupiter at various times. Our vantage point allows us to see this happen because Jupiter's shadow lies west of the planet. Ganymede in particular is far enough away from Jupiter so that we can observe the entire shadow event occurring clear of the planet's limb. Each moon orbits Jupiter in different periods, but occasionally multiple events occur on one night. As examples, this month you can observe multiple events on August 7, 14, 21, and 30. (See chart at left.) Times are Eastern Daylight Time. On the East Coast of the United States dawn will interfere with some of the later events.

The easiest of Saturn's moons to spot is Titan, a magnitude 8.3 disk through small scopes. Iapetus is an enigmatic moon of Saturn, varying in brightness due to a difference in the reflectivity of its hemispheres. It's dimmer — magnitude 11.9 — at eastern elongations, one of which occurs on the second week of August. Following August 15, Iapetus moves from east of Saturn to its west, brightening as it does so. Its western elongation takes place in the third week of September when it will shine at magnitude 10.2.

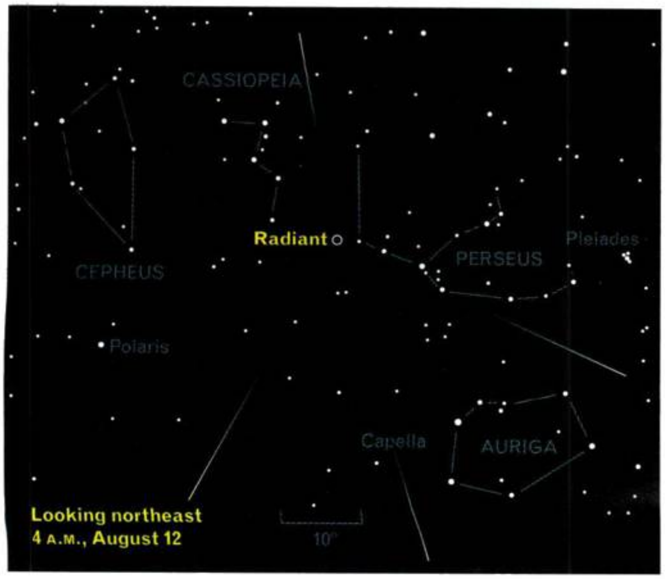
### It's Raining Solar System Debris

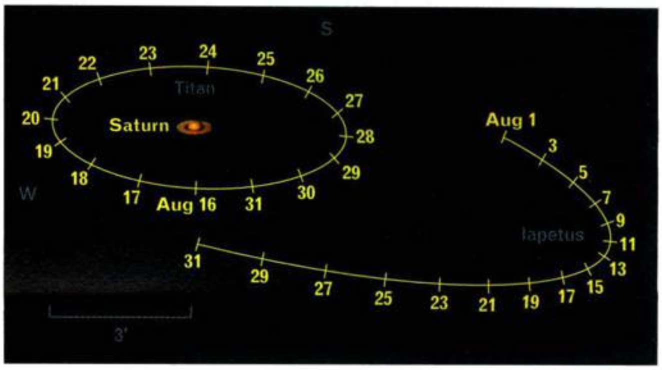
The Perseids generally produce a fine display each year, with this year's shower's activity running from July 17 to August 24. However, a waxing gibbous moon interferes with the night of maximum on August 12, although it sets about an hour before dawn. This offers only a brief time to view the meteors in a dark sky. However, since meteor activity tends to rise before dawn and the possibility of fireballs increases as dawn breaks, the chances are that most observers will see a pretty good display.

Often overlooked by Perseid viewers are two other showers active over a similar time period. Meteors from these showers are easily identified because they move in entirely different directions from the Perseids. Most notably different are the Kappa Cygnids, active from July 26 to September 1 and peaking on August 19. Distinctive by their slow-moving tracks and often yellowish in color, the meteors can be very bright in spite of their low rates.

The North Delta Aquarid shower is active from July 16 to September 10 and peaks on August 13, but it's less active than the southern branch of last month. Even so, due to the more northerly radiant, activity can be observed easily from northern latitudes. Meteors tend to be medium speed and principally faint, so wait until after the moon has set before you try to observe them.

Take along a pair of binoculars when observing meteor showers. If you see a bolide, try to catch the remnant's twisting ion trail through the binoculars.





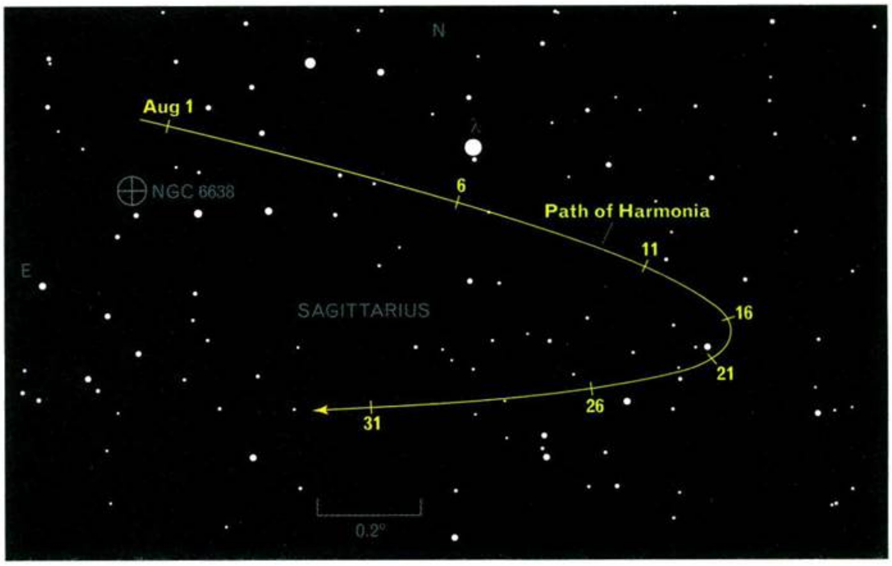
### Last Chance to Observe Comet LINEAR

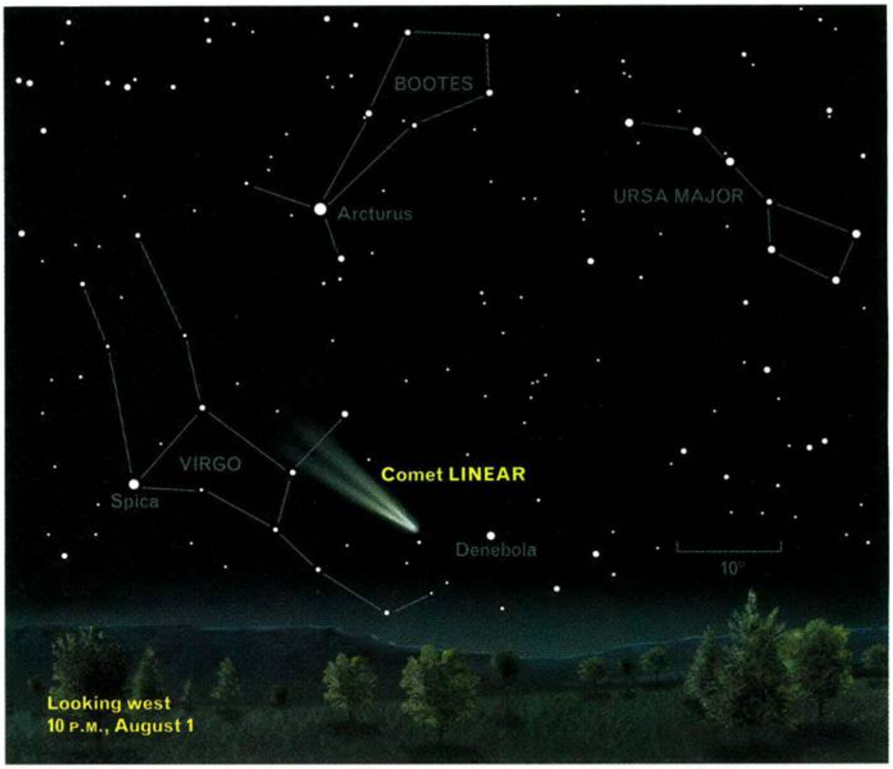
It's a swan dive for the evening Comet LINEAR (C/1999 S4). Catch it before it plunges into invisibility during the first week of August.

To maximize your comet-watching enjoyment, observe no later than August 1st if you want to see the tail in a dark, moonless sky. Find a site with the city to the east and few towns to the west. Light pollution will otherwise hide the tail with an obscuring veil.

LINEAR hangs low above the western horizon about 90 minutes after sunset. Extend your arm, and a bit above one fist width you'll find the comet. As of press time indications were that it would likely require binoculars to see. If it's brighter than forecast, you should be able to spot a short tail pointing away from the sun, to the upper left. Spend some time observing LINEAR at a variety of magnifications, and remember to look for jet activity near the core at high power.

Apart from overall shape and brightness, jet activity will be the only feature to look for once we reach the night of August 2. LINEAR swings low past the sun while the crescent moon fattens. You'll be lucky to even detect it in a large scope by mid-month.





### A Teapot Anchors an Asteroid

As if caught in the beam of a headlight, the rocky asteroid 40 Harmonia can't escape a bright star in low-power fields all month. It will be easy to follow this minor planet many nights in a row as it arcs slowly near the top of Sagittarius's teapot, Lambda Sagittarii.

Whenever Earth in its orbit catches up to and passes another object, we see the object do a graceful westward arc on the sky (a retrograde loop). 40 Harmonia appears to perform a tight switchback next to a naked-eye star.

From the city with an 8 inch or from the country with a 4-inch scope, you'll have no trouble spotting the 10th-magnitude asteroid. Point your scope at Lambda Sgr, shift it south a bit, and 40 Harmonia will be in sight. Close approach to Lambda Sgr is 7' on the evening of the 6th. Stars of similar brightness litter the background of the Milky Way, so check the map.

While you're at it, scoot 40' east of Lambda Sgr to see if you can detect the globular star cluster NGC 6638. Although it is a magnitude brighter than 40 Harmonia, the globular's light spreads over 2', making it appear fainter and fuzzier. Its individual stars are too faint to resolve.

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*Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.*

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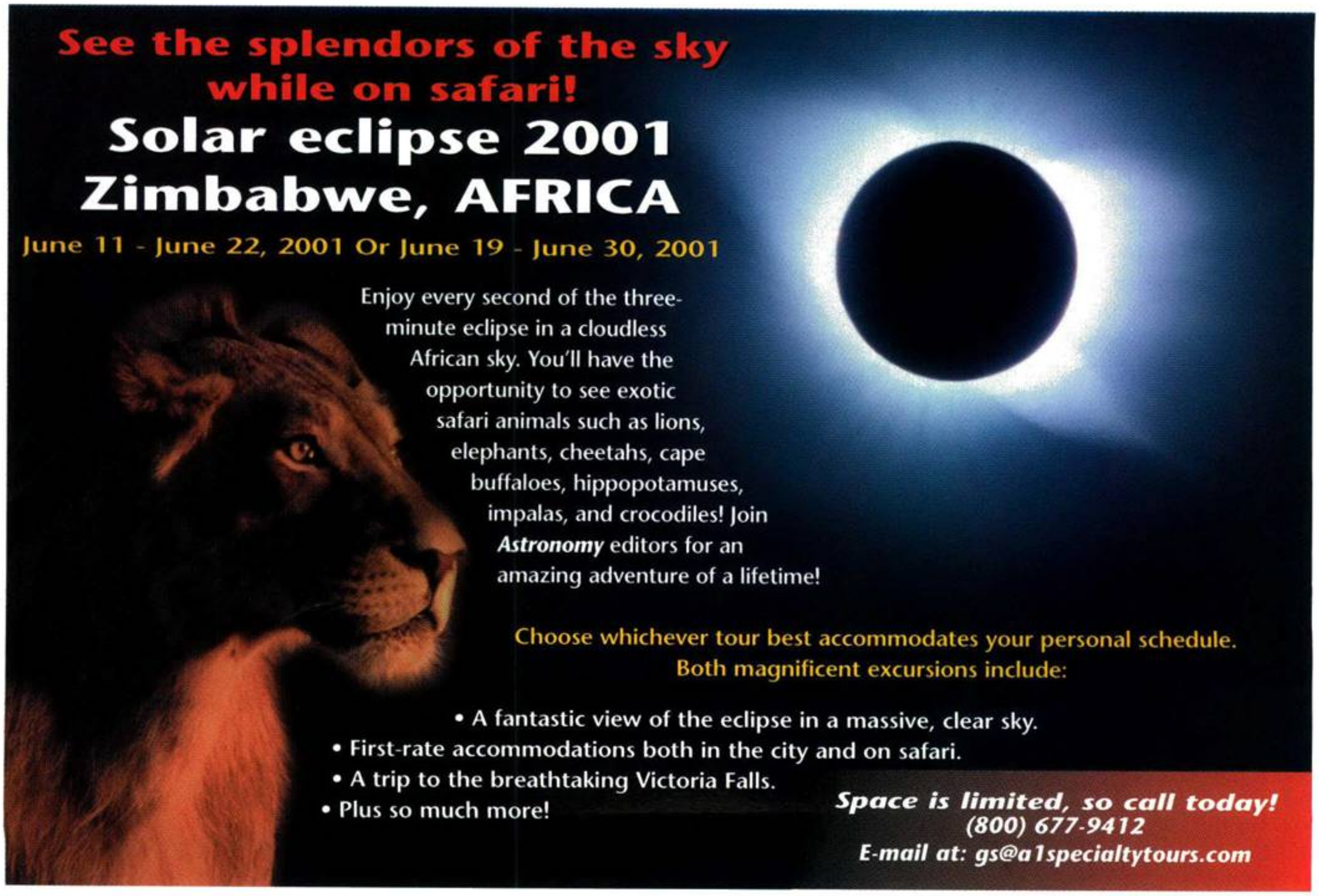

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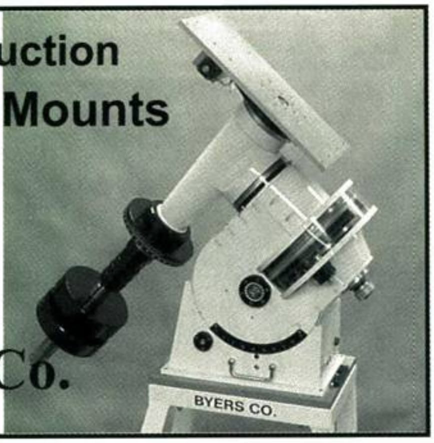

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# Diving into Darkest Africa

by Richard Talcott

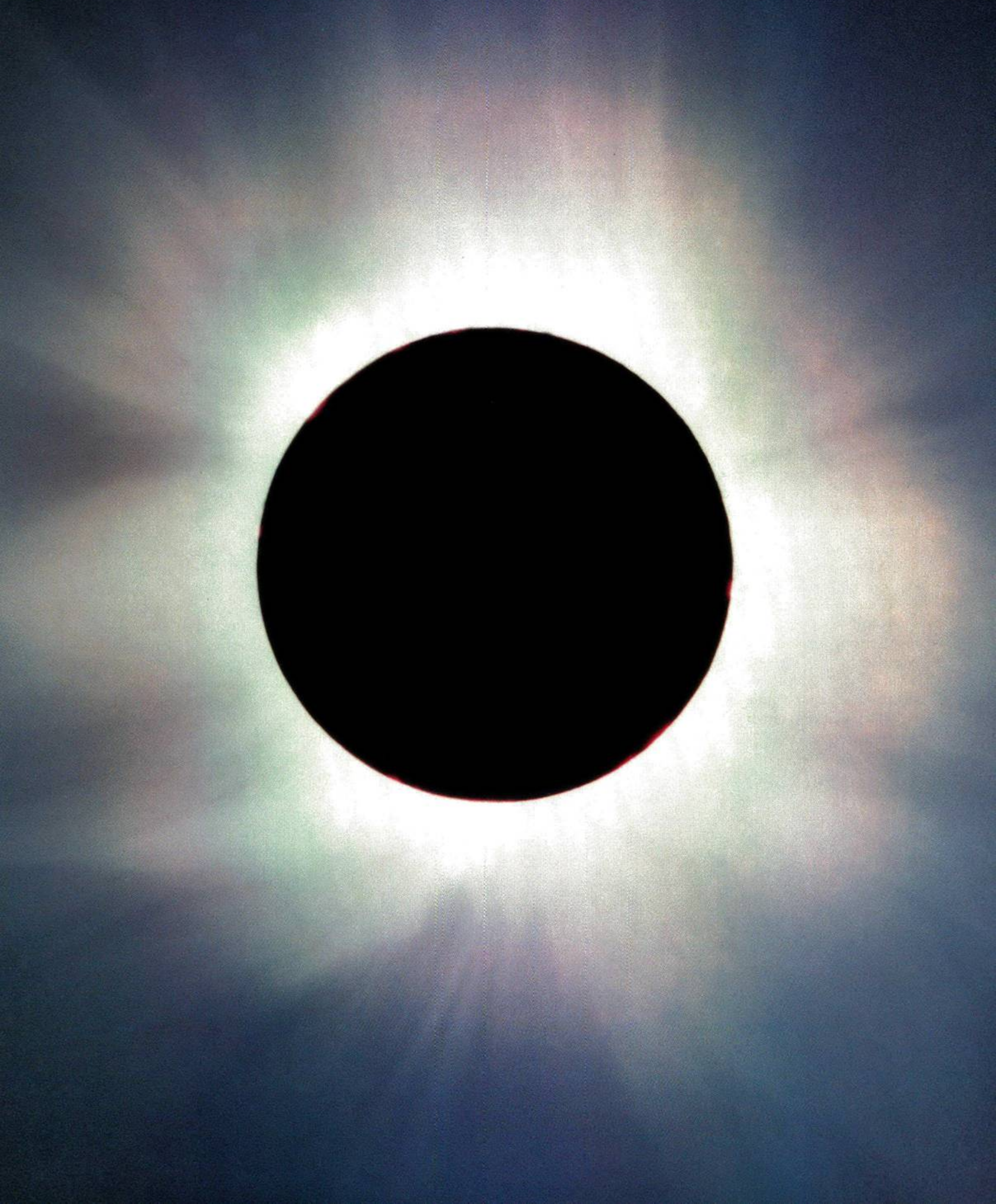
Everyone likes to dream. Surfers dream of the perfect wave. Actors dream of the perfect role. Wine connoisseurs dream of the perfect vintage.

Eclipse chasers are no different. For them, the perfect solar eclipse combines a long period of totality with nary a cloud in the sky. Throw an exotic locale into the mix and you'll get any eclipse watcher's juices flowing. And while perfection can be hard to achieve, the eclipse of June 2001 comes close, offering the best chance in 10 years to turn this dream into reality.

The first solar eclipse of the new century cuts a narrow swath across the South Atlantic and southern Africa on June 21, 2001. At its maximum off the west coast of Africa, the sun will disappear for nearly 5 minutes — more than twice as long as the best provided by the European eclipse of August 1999 and the

**Right: The August 1999 eclipse revealed a rounded corona nearly at solar maximum. Eclipse chasers in Africa should see the same.** Jeffery C. Buell
**Below: The black and white stripes of zebras will contrast nicely with eclipse-darkened skies during daylight hours.** TSM

mises a grand spectacle over southern Africa.



longest of any eclipse since June 1992. Between 4½ and 3 minutes of darkness await those on the center line as the path of totality slices across Angola, Zambia, Zimbabwe, and Mozambique.

Even better, the weather prospects rate among the best for any eclipse in decades. By June southern Africa is well into its annual dry season and clear, sunny skies are the rule along most of the track. Exquisite views of fiery red prominences, the ghostly corona, and twilight hues circling the vast horizon should greet most people who venture into the path of totality.

Coming as it does on the Southern Hemisphere's winter solstice, the eclipse will give locations along the path of totality their shortest "day" in recorded history. In June this tropical region experiences daytime highs averaging in the low- to mid-70s (20° to 25° C) while nighttime lows typically dip into the 40s (5° to 10° C).

## *Darkness at Dawn*

Totality begins at sunrise in the South Atlantic Ocean approximately 250 miles (400 km) southeast of Uruguay. Although the dark umbral shadow — where the moon totally hides the sun's surface from view — doesn't touch South America, a broad region of the east-central part of the continent lies in the lighter penumbral shadow. Residents there will see a partial eclipse with the moon taking a bite out of the sun as the pair rises on the 21st. The deepest eclipse occurs along the southern coast of Brazil, where 90 percent or more of the sun will be hidden as it rises out of the Atlantic.

The eclipse track then heads east across the Atlantic. No major landfall occurs before the eclipse reaches its maximum in the South Atlantic some 700 miles (1,100 km) west of the Angolan coast. At that point, the sun disappears for 4 minutes and 56 seconds and the path of totality stretches 120 miles (200 km) wide.

Half an hour later, the shadow makes contact with the coast of Africa, coming ashore about 85 miles (140 km) north of the port town of Lobito, Angola. Here the sun departs the scene for up to 4 minutes and 36 seconds. The shadow races across Angola at about 1,400 miles per hour (2,300 kph) and completes its entire west-to-east traverse of the continent in just under 45 minutes.

Angola presents perhaps the best and worst for this eclipse. Totality lasts longest, staying above 4 minutes along the center line across the country. Angola features the best weather prospects as well, particularly on the broad plateau that covers most of the country's interior. Statistics show this region remains clear more than 90 percent of the time in June and some spots achieve 95 percent or better. The only part of the globe with clearer weather at this time of year is the Sahara Desert.

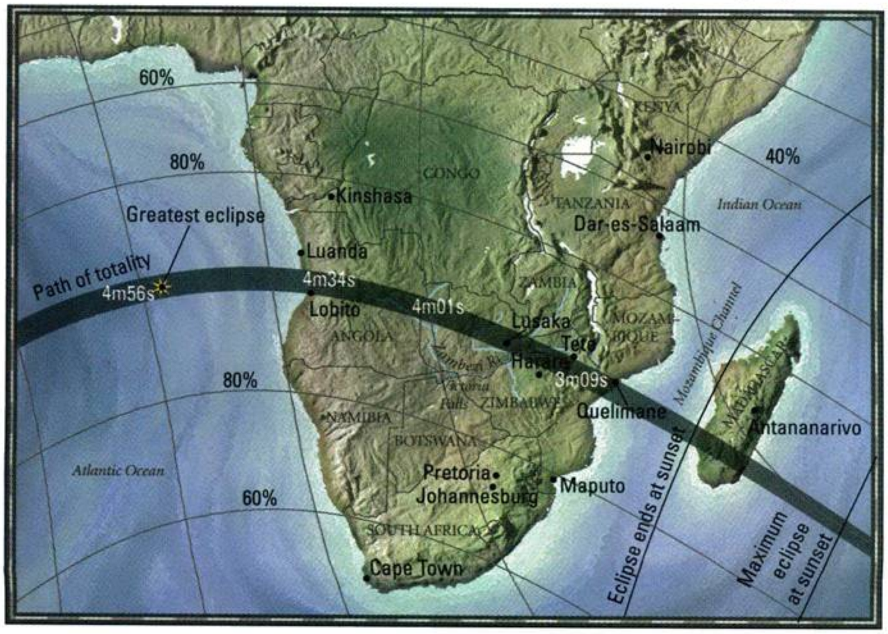
Yet Angola suffers from the aftereffects of a decades-long civil war that occasionally still flares up. Bandit attacks, police brutality, and unexploded land mines contribute to making Angola an unsafe destination for foreigners. Although none of the other countries in the eclipse path faces such intense political strife, it pays to keep up with the latest news. The U.S. State Department provides up-to-date information about travel to southern Africa. You can check out the department's consular information sheets for any country at http://www.travel.state.gov/.

After exiting Angola, the path of totality crosses into Zambia. Lusaka, Zambia's capital and the only major city in the entire path, lies 20 miles (35 km) south of the center line. From Lusaka, day turns to night for 3 minutes and 14 seconds, about 20 seconds less than on the center line north of the city. On the center line, the totally eclipsed sun lies 31° above the northwestern horizon a little after 3 P.M. local time.

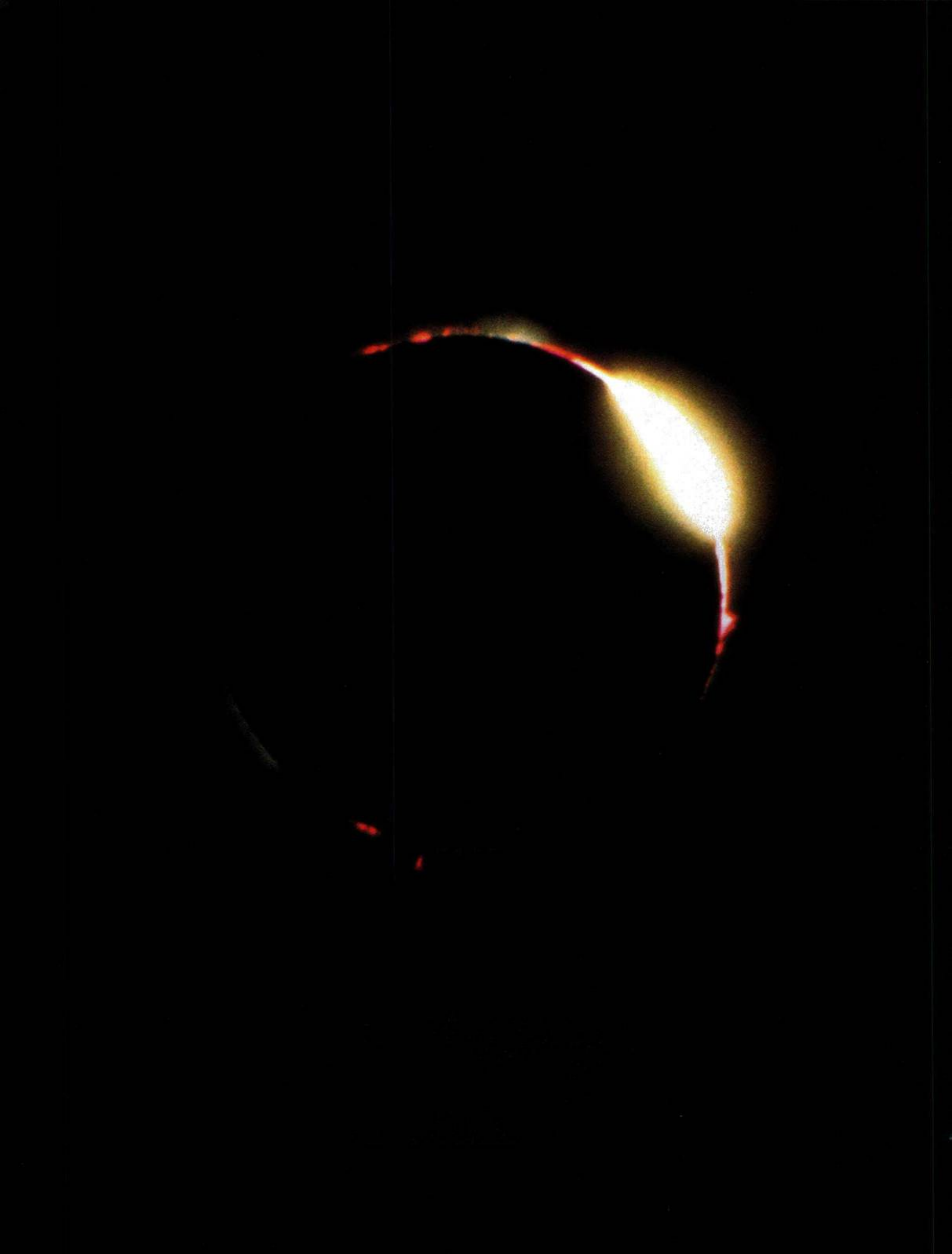
Most of Zambia enjoys weather prospects only slightly worse than Angola. Satellite images show about an 80 percent chance of clear skies in this country — slightly better in the west and slightly worse in the east. Unfortunately, haze may well hinder your view of totality from both Zambia and Angola. June marks the beginning of the annual burning of the African grasslands. Although much of this man-made burning takes place north of the eclipse track, some of the haze drifts south and could make the fainter outer corona hard to see.

After Zambia, the umbral shadow straddles the border between Zimbabwe and Mozambique before entering completely into the latter country. Harare, the capital of Zimbabwe, lies about 60 miles (100 km) south of the path of totality and its residents will witness a 98 percent eclipse. Fortunately, Zimbabwe has a well-developed tourist industry and road system, making travel from Harare into the path relatively easy. On the center line north of the city, the sun goes into hiding for 3 minutes and 24 seconds. One potential problem is that most of the roads inside the path run perpendicular and not parallel to it. If the weather should turn cloudy as eclipse time approaches, it could be difficult to reach a sunnier location.

However, weather prospects for Zimbabwe look favorable: The likelihood of clouds runs only a few percentage points higher than in eastern Zambia. Because northern Zimbabwe lies on the Zambezi escarp-



**Left: The narrow eclipse path cuts a slice through south-central Africa.** *Astronomy:* Terri Field
**Right: Even residents with long memories can't recall Southern Africa's last eclipse.** TSM



ment — an area that rises about a mile above the valley carved by the mighty Zambezi River — the odds of clear weather are significantly better than across the border in Mozambique.

## *Safari Adventure*

Both Zambia and Zimbabwe offer plenty of opportunities to experience a safari along with the eclipse. Most of the animals that make Africa so enticing to outsiders — elephants, giraffes, and hippopotamuses, to name a few — call the parks and wilderness areas in these countries home. Watching the giant animals as Mother Nature fools them into thinking nightfall is imminent should prove to be an eclipse highlight.

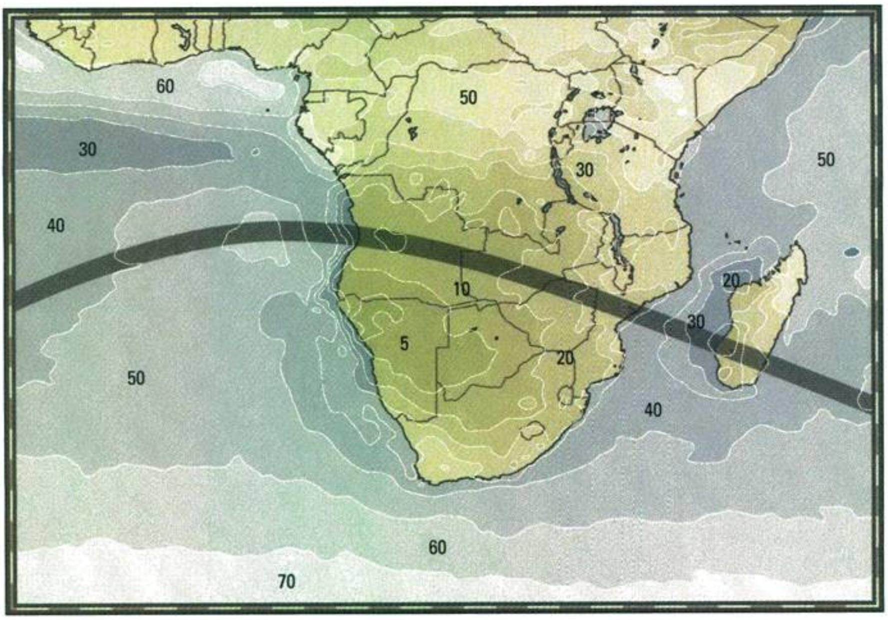
Although the local lions, hyenas, and rhinoceroses may look dangerous, it's the little creatures you really need to worry about. Insects here carry malaria and a host of other diseases, while water and food can harbor bacteria, viruses, and parasites. If you plan on seeing this eclipse, check with your doctor a few months beforehand to line up any necessary shots. The U.S. Centers for Disease Control and Prevention maintains a website that provides travelers with up-to-date health information at http://www.cdc.gov/travel/.

The worst weather prospects on the continent come in Mozambique, though the chances of seeing totality still run better than 50 percent. On the center line, totality endures for more than 3 minutes all the way to the coast, where the shadow leaves the continent near the delta of the Zambezi River.

**Above: African eclipse chasers come in a wide variety of shapes and sizes.** TSM

**Left: Look for the "Diamond Ring" just before and after totality.** Eduardo Gastelum

**Below: Cloud cover averages in June for Southern Africa.** *Astronomy:* Terri Field



After crossing the Mozambique Channel, the umbra touches land once more in southern Madagascar. This exotic island, the fourth largest in the world, lies 250 miles (400 km) off the African coast. Totality lasts approximately 2½ minutes along the center line and, with day nearing its end, the sun will be low in the sky.

The mountain chain that runs down the spine of the island controls the weather. The easterly trade winds blow in off the Indian Ocean, and the mountains wring most of the moisture out of the winds. That keeps the eastern side of the island cloudy and drenched, and tropical rain forests rarely offer good prospects for seeing an eclipse. Yet the mountains leave the island's western side with a semiarid climate. Only interior Angola and western Zambia have a better chance for clear skies than southwestern Madagascar.

The umbral shadow continues briefly into the Indian Ocean before lifting back into space, not to return for a year and a half. Amazingly, when it does, on December 4, 2002, it will traverse the same region of southern Africa. (The central coast of Angola will actually see its second total eclipse in 18 months — not bad when you consider that, on average, a spot on Earth sees totality only once in roughly 300 years.) Angola, Botswana, Zimbabwe, South Africa, and Mozambique witness a total eclipse the next time around. Unfortunately, the eclipse comes during the summer wet season and totality lasts at most 1 minute and 30 seconds.

Then, after a long traverse of the Indian Ocean, the shadow hits Australia. Residents and visitors will see only about 30 seconds of totality north of Adelaide, but Australia should provide better weather prospects than Africa. Regardless, the June 2001 eclipse offers much more to dream about. Who knows — it could turn out to be the perfect eclipse. A

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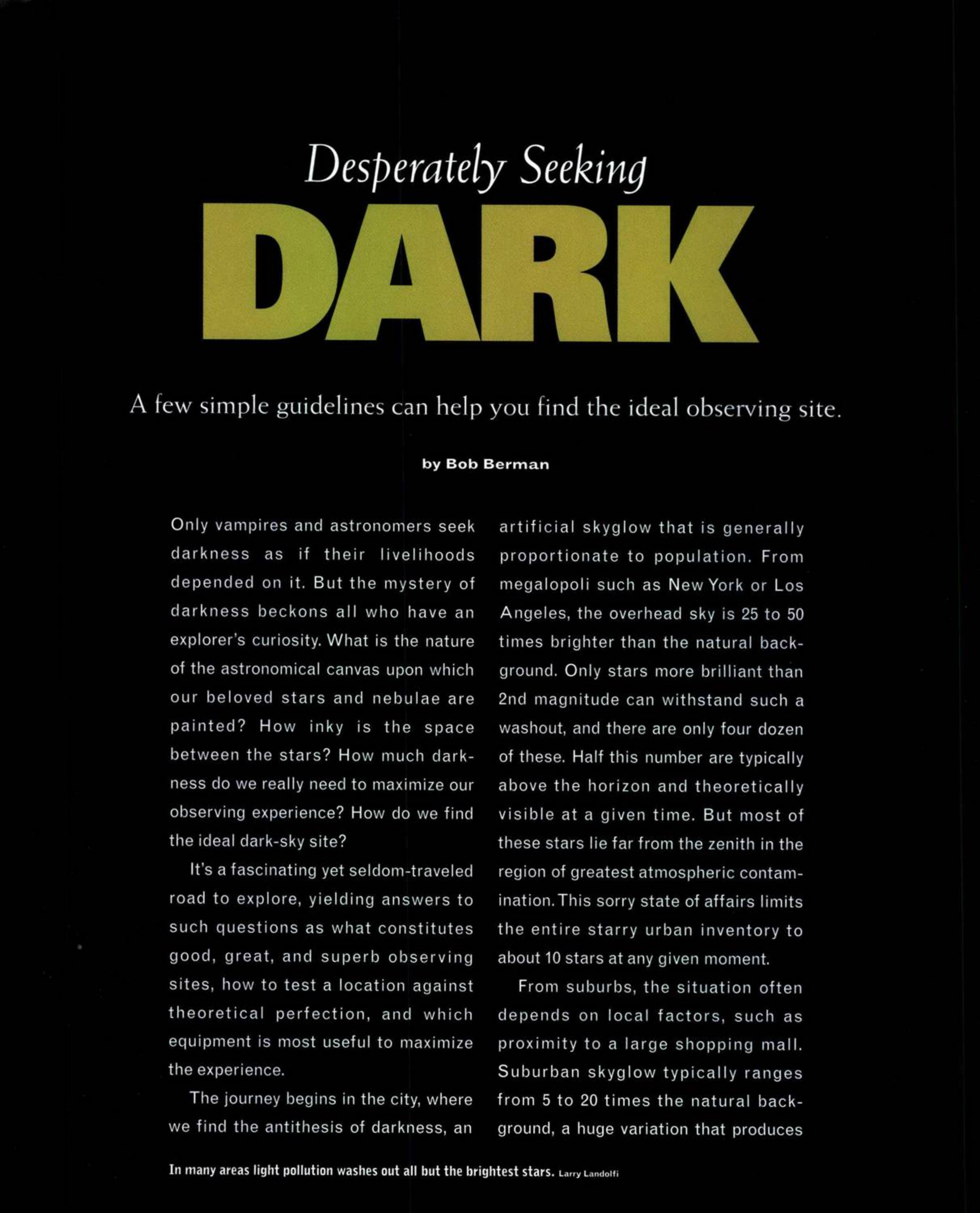
*Richard Talcott is an associate editor for* Astronomy *and coauthor of* Chasing the Shadow.

# *Desperately Seeking* DARK

A few simple guidelines can help you find the ideal observing site.

**by Bob Berman**



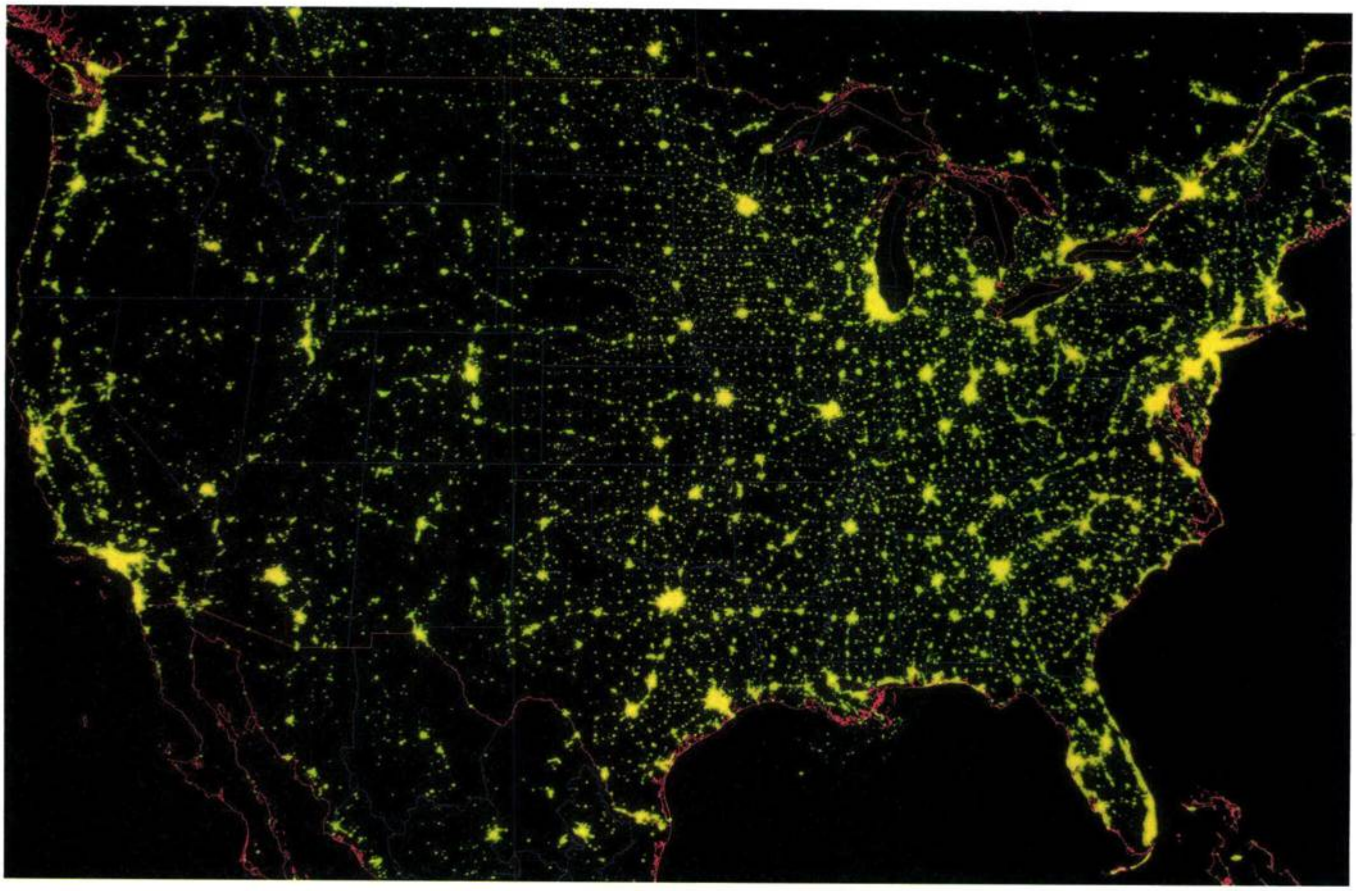
Only vampires and astronomers seek darkness as if their livelihoods depended on it. But the mystery of darkness beckons all who have an explorer's curiosity. What is the nature of the astronomical canvas upon which our beloved stars and nebulae are painted? How inky is the space between the stars? How much darkness do we really need to maximize our observing experience? How do we find the ideal dark-sky site?

It's a fascinating yet seldom-traveled road to explore, yielding answers to such questions as what constitutes good, great, and superb observing sites, how to test a location against theoretical perfection, and which equipment is most useful to maximize the experience.

The journey begins in the city, where we find the antithesis of darkness, an artificial skyglow that is generally proportionate to population. From megalopoli such as New York or Los Angeles, the overhead sky is 25 to 50 times brighter than the natural background. Only stars more brilliant than 2nd magnitude can withstand such a washout, and there are only four dozen of these. Half this number are typically above the horizon and theoretically visible at a given time. But most of these stars lie far from the zenith in the region of greatest atmospheric contamination. This sorry state of affairs limits the entire starry urban inventory to about 10 stars at any given moment.

From suburbs, the situation often depends on local factors, such as proximity to a large shopping mall. Suburban skyglow typically ranges from 5 to 20 times the natural background, a huge variation that produces

**In many areas light pollution washes out all but the brightest stars.** Larry Landolfi



**This U.S. Defense Department satellite photo shows where to go — and where not to go — to observe the night sky.** International Dark-Sky Association

a 1.5-magnitude difference in star visibility. A sky that barely shows 3rd-magnitude stars looks very different from one that displays those of magnitude 4.5 because the number of stars increases exponentially and inversely with brightness. There are only 46 stars in the magnitude 2 to –2 range, but 6,000 in the brightness bin from 2 to 6. Descend another four magnitudes to 10 and you'll see more than 80,000. This is why a natural dark background is so crucial to experiencing the full drama of the heavens.

Although a truly black sky is not attainable from Earth because of natural illumination and the atmosphere (see "When Nature Isn't Nice," page 85), simple aesthetics demand as dark a background as possible. A star cluster seen against a milky backdrop loses its impact, which is why film and CCD astrophotographers routinely crank the contrast. They synthetically manufacture something they have never seen in person — white stars against a black backdrop.

For those who crave true high-contrast views, specific tricks can create "black magic." Ideal binoculars for astronomy — those with 7mm exit pupils that maximize brightness, such as 7x50, 10x70, or 11x80s — also crank up the sky's background glow. Beneath truly dark skies, this is no problem: The ability of "night glasses" to brighten the target and bring out the 50,000 stars visible down to 9th magnitude makes binoculars an amazing accessory. But in suburban skies that suffer even a small degree of ambient milkiness, these same binoculars harm the image by excessively brightening the diffuse background. Suddenly you're back to white stars on a milky canvas. In such conditions, it's better to use lighter 7x35 or 10x50 binoculars, whose 5mm exit pupil lets in less light and yields a darker and more satisfying backdrop.

With telescopes, you can increase the magnification to darken the field. So consider this option when reaching for the eyepiece: Determine not only how large or bright your target will be, but how aesthetically dark to make the background. And don't forget broadband light-pollution filters for all types of objects as well as narrow bandpass filters for specific types of nebulae. For less than $100 they can make a dramatic difference in screening out artificial skyglow.

## Black Is Beautiful

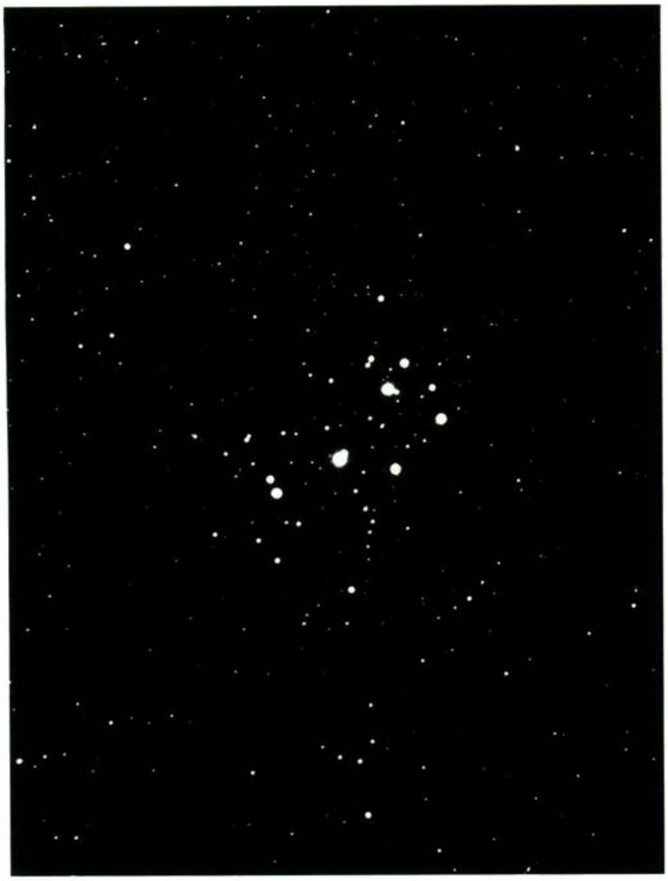
You know you're in a really dark spot when so many new stars crowd the heavens that it takes a few moments to find the constellations. Without detailed charts to gauge the limiting magnitude, it's helpful to have a quick way of telling what class of dark sky you've reached. Here's an easy guide to evaluate your sky conditions, using stars that are visible from mid-Northern latitudes.

Poor: Nothing fainter than 2nd magnitude (Polaris, Orion's belt, Big Dipper, Cassiopeia) appears. You can see fewer than 20 objects in the entire sky.

Fair to Poor: The Little Dipper's bowl contains the two end stars, Kochab (magnitude 2) and Gamma (magnitude 3), and no others. There is no trace of Orion's "head."

Fair: A third star (magnitude 4) glows in the Little Dipper's bowl. Orion's three "head" stars are faintly seen (dimmest are 4.4 and 4.5). You can see six stars (the dimmest is magnitude 4.4) in the Pleiades (M45).

Fairly Good: All four bowl stars of the Little Dipper are visible (the faintest is magnitude 5). The Milky Way appears



**From a superb dark site, you can see 11 to 14 members of the Pleiades open star cluster (M45) with your naked eye.** Yerkes Observatory

on moonless nights. The Beehive Cluster (M44) is visible in Cancer. The Andromeda Galaxy (M31) can be discerned.

Very Good: The Milky Way is distinct and shows detailed structure. The Andromeda Galaxy is obvious. You can see eight Pleiads (dimmest 5.4). Globular cluster M13 in Hercules may come and go (magnitude 5.9), as may open cluster M35 in Gemini. You can glimpse individual stars in M44 using averted vision.

Excellent: M13 is easily and steadily visible. A string of four stars (magnitude 5.6) clearly radiates from the Mizar/Alcor duo in the Big Dipper's handle. Orion's belt is embedded in a swarm of dim stars (magnitude 6 and fainter). The Eagle Nebula (M16) and the Omega Nebula (M17, magnitude 6) are visible. If up, the Milky Way dominates the sky. Uranus (5.7) is obvious. M35 is easily visible at Gemini's feet.

Superb: The spiral galaxy M33 is faintly visible as a moon-sized blob in Triangulum. You can see 11 to 14 Pleiads. The winter Milky Way looks more impressive than the summer Milky Way when seen from an outstanding site.

## It's Perfectly Clear

Hints of what lies ahead occur even before sunset. A deep blue daytime sky is an excellent sign. Low humidity usually creates transparent air when dust and nearby artificial lights are absent (though seeing will often be poor following a cold frontal passage). Because water vapor reduces transparency and scatters light, the drier the air, the better. Such impediments manifest themselves in the daytime sky as a distinct

### WHEN NATURE ISN'T NICE

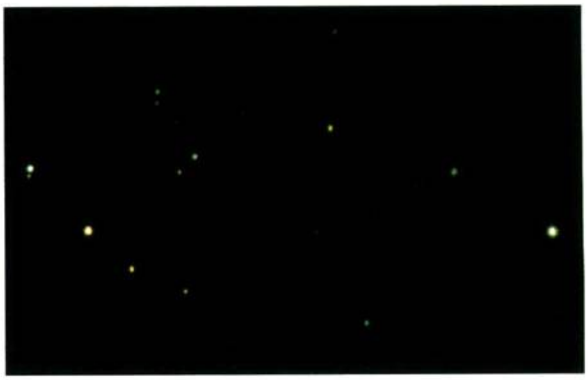
Natural background. That's the key. The degree of light pollution is usually compared with the purity of a natural sky. But how dark is it?

It isn't black. More light naturally radiates from the sky as a diffuse glow than from all the stars combined. Together they offer enough light to let you see your way on the darkest country road, except where an overhanging canopy of trees blocks the heavens.

This natural illumination has four components. The brightest is airglow, a faint luminescence emanating from oxygen atoms in the upper atmosphere. It varies quite a bit and gets especially bright during times of sunspot maximum, like this year. Solar ultraviolet energy excites the oxygen atoms, causing them to radiate light. The radiance is too faint to stimulate the cone-shaped color receptors in our retinas, but if we were able to see its tint, the glow would appear green.

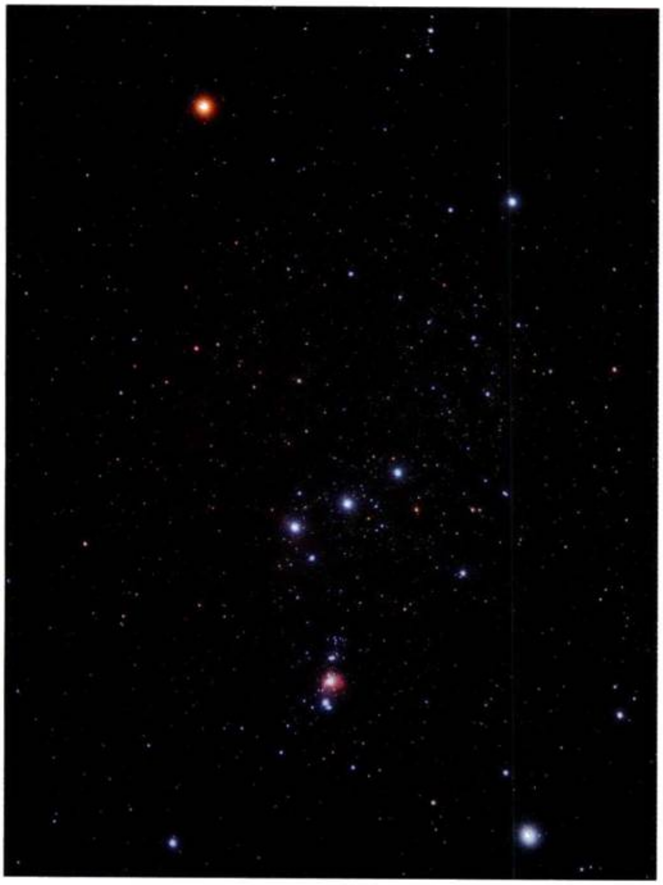
The second source comes from sunlight reflected by interplanetary dust particles. This is the famed zodiacal light, which is occasionally as bright as the Milky Way. It's preferentially seen near the ecliptic. The cone-shaped glow, with the fat end on the horizon, is brightest just before the start of an autumn morning twilight or in a spring evening's post-twilight sky when seen from mid-Northern latitudes.

Third in the rogue's gallery is the scattering of starlight as it passes through the atmosphere. By day, sunlight bounces among air molecules, with the shorter blue wavelengths six times more prone to this scattering effect than red, which is why we have a blue sky. By night, the same process would keep the sky blue if only our eyes had not switched to the color-blind rod-cell vision used in low-light situations. Still, you can dimly perceive a blue night sky within two days of full moon.



**You can only see the entire Little Dipper, which is part of Ursa Minor, from relatively dark areas.** Robert C. Mitchell/Hansen Planetarium

Finally there's the background glow from the unresolved stars and nebulae of our own galaxy. Naturally, this is much brighter along the galactic plane where it takes the form of the Milky Way, which is brightest at nightfall from August through October when we face inward toward the galaxy's center.



**From an excellent dark site, Orion's belt is surrounded by dim stars. You can easily see Orion's three head stars (top) from a good site.** Ross Salomone

brightening near the horizon and a zenithal shade of light or medium blue instead of dark blue. A superb sky will barely lighten in its lowest 10° above the horizon. Indeed, even if the overhead is a deep blue, a pronounced milkiness at the lowest sector of the sky's hemisphere is a sign that the night will be good, maybe even very good, but not exquisite.

Distancing yourself from urban and even suburban areas is, of course, critical. Driving just 25 miles from midsized cities often yields amazingly good skies. Seventy miles from even the largest cities can provide everything an observer would want. Beyond a certain distance, skies do not improve, so there's little benefit in favoring the Yukon over, say, New Mexico. Once you've trekked into New York's isolated Adirondack Mountains, or New Hampshire's White Mountains, there's little reason to drive another three hours to the middle of Maine. One might pick up an extra 0.1 magnitude, but this is scarcely discernible to the eye.

Also, choosing the right meteorological occasion (when air is dry, for example) may yield greater benefit than going deeper into the wilderness at a time of moderate humidity. Finally, when air is clean and dry, the glow from a single large city 60 miles away will mostly brighten the lower sky elevation in that one direction. If you've traveled to where the gleam is confined to a "dispensable" part of the heavens (such as the lower half of the northern sky), it may present no impediment whatsoever. Why go farther?

## FIGHT LIGHT POLLUTION

To learn more about how to combat light pollution, visit the International Dark-Sky Association's website at www.darksky.org/.

## PUBLIC DARK SITES

To find a good public dark-sky site near you, visit the following websites:

ourworld.compuserve.com/homepages/pharrington/Dssd.htm
ourworld.compuserve.com/homepages/rawhide_home_page/sitedata.htm
www.seds.org/TAC/sites.html (California)
www.psiaz.com/polakis/azsites/azsites.html (Arizona)

## TELL US YOUR FAVORITE DARK-SKY SITE

Please share your favorite dark-sky sites with *Astronomy* and tell us a little bit about them. *Astronomy* plans to compile the list into a future article. Visit our website at www.astronomy.com or write to Dark Sky Sites, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187.

Where can you find skies that are the best of the best? The famous nighttime satellite photo of the artificially illuminated United States (page 84) provides rough guidance. But the situation is much more promising than that nearly wall-to-wall lighting would suggest.

Speaking to astronomers in various parts of the country makes it clear that there are classes of excellence. Western skies are legendary for their clarity. Montana, for example, has routinely dry air, vast unlighted tracts, low population density, and a high elevation. In reality, anyone willing to drive an hour from absolutely anywhere in the United States, including the fabled land of murk, the Northeast corridor, can usually experience very good or excellent conditions.

Deserts supply dry air; higher elevations ensure that some of Earth's atmosphere is below you. The combination of a place that leaves you both high and dry and that also is far from human habitation (like Mongolia's Gobi Desert) is ideal, with seeing usually reaching optimum levels at higher altitudes. Personally, the most intensely transparent skies I have ever seen have been in the vast desert of southern Iran, above 7,000 feet (2,100 meters) in the Himalayas, on South Pacific islands, and in the spine of mountains running down Central America and into the Andes. I have heard that the Australian outback is also excellent, although I have never been there myself.

"Superb" skies are rare, a gift given grudgingly and not always predictably. Once the eye dark-adapts under such circumstances, the observer stands in a stellar fairyland. It is the outer-space experience. As if to recall a distant time and place, one returns to the glittering infinitude that brought many of us to our astronomy passion in the first place. No, it is not pitch-black, and it never will be. But somehow, here is perfection. A

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*Bob Berman writes* Astronomy's *"Strange Universe" column. He is author of* Cosmic Adventures *and* Secrets of the Night Sky.

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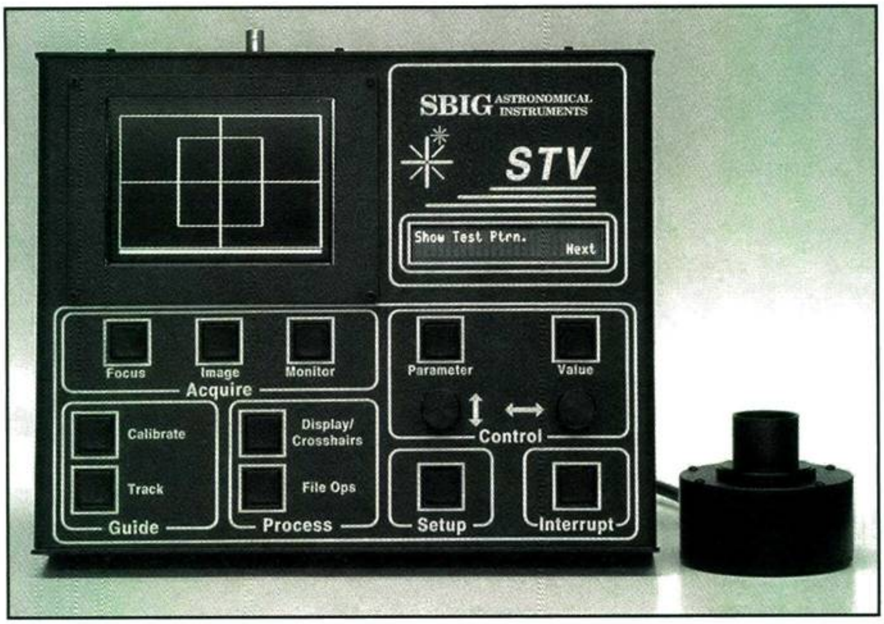
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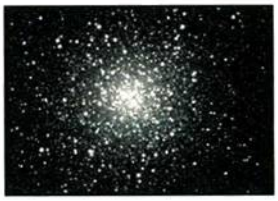

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# GIMME SHELTER

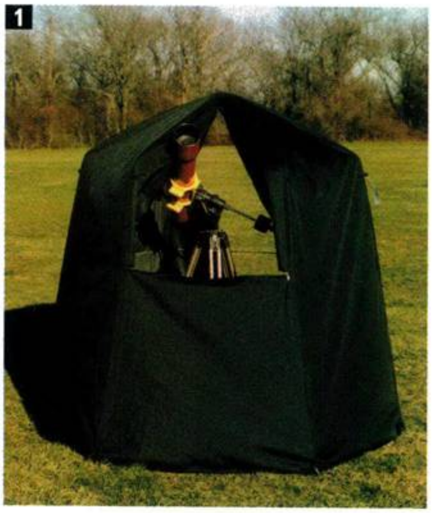
*Innovative designs in portable observatories mean you can take it with you.*

**by Phil Harrington**

Think of it as a dream come true: your own observatory that not only offers shelter against wind, cold, and local light pollution, but also makes setting up and breaking down your telescope a snap. Permanent observatories are wonderful but impractical, because most amateur astronomers must travel to their favorite observing sites. In recent years, however, several manufacturers have introduced products that combine the benefits of a permanent observatory with the convenience of portability.

Here's a look at six portable observatories in three different categories. The simplest — telescope shelters — includes TeleDome from Clear Night Productions and ShelterDome by Kendrick Astro Instruments. Camping-style tent/shelters include Kendrick's Observatory Tent and Galileo by North Peace Outdoor Equipment. Finally, SkyTent International and the Tradewinds Company each produce a semipermanent observatory: SkyTent and DarkSite Domes, repectively. All six observatories offer overlapping features that address the various needs of amateur astronomers.

**SkyTent International offers a portable dome with a snap-together frame that can be assembled by one person.** David Phelps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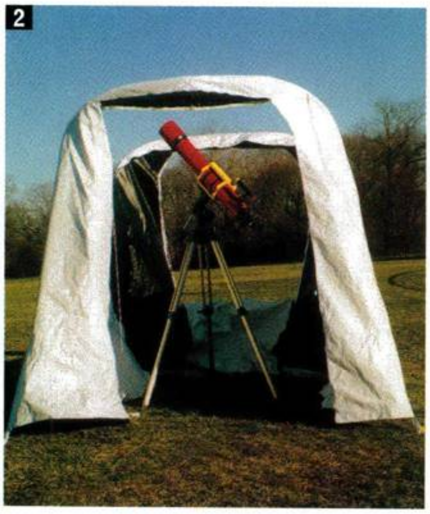
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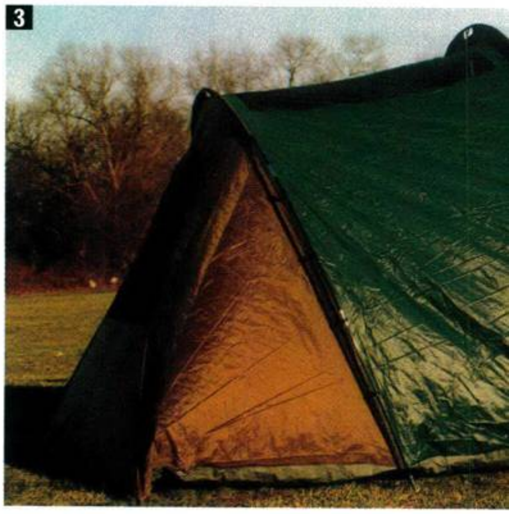
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## Telescope Shelters

Both the Clear Night TeleDome and Kendrick Shelter-Dome set up easily, come down quickly, and are light enough for easy transport. Neither has a sewn-in floor.

The TeleDome is made of steel, aluminum, and Cordura fabric. Unlike the others, the TeleDome requires almost no assembly. Simply unfold for use. To set it up, undo the two Velcro straps and stand the TeleDome on end. Grasp the ends of the frame while spreading your arms outward until the outer frame members click into detents on the central pivot. Place each of the six horizontal support braces into its respective bracket and you're done.

After you put your equipment inside, the door flap zips shut. Turn around and unzip the T-shaped half opening in the opposite wall for a waist-high view covering a horizontal span of about 60°. Unfortunately, it's hard to keep the unzipped flaps out of the way. Some attached Velcro straps would solve this problem. Observers with lower-riding reflectors will find that peering through the doorway itself affords a better view. The zenith is not accessible through either opening without first offsetting the telescope from the dome's center.

The most inconvenient part of the TeleDome is rotating it. The user must pick up the entire 20-pound assembly and turn the whole unit around manually. I am 6'4" and had no trouble reaching the top of the dome. Shorter users may find it difficult to rotate the TeleDome without bumping their telescopes. And, regardless of your height, expect to unhook a couple of the horizontal support braces when turning it.

TeleDome's fabric is completely opaque to light pollution, and it slowed condensation. However, its tall profile makes it less effective against the wind. During field tests, a 20 mile-per-hour wind gust blew it over. Staking it to the ground holds it in place but limits its usefulness.

The TeleDome is currently offered in two models measuring 7'6" at their

### PROS AND CONS

| | **1 TeleDome** | **2 Shelter-Dome** | **3 Observatory Tent** | **4 Galileo** |
|---|---|---|---|---|
| Strengths: | Easy setup.<br>Very effective against local light pollution and condensation.<br>Lightweight. | Easy setup.<br>View entire sky with little obstruction from frame. | Lightweight. Weatherproof (with fly). Sleeps three to four. Unobstructed view of all horizons when observatory is open. Ripstop flooring. | Lightweight. Weatherproof. Sleeps three to four (w/o telescope). Very simple setup. Opaque walls effective against pollution. Ripstop floor and walls. |
| Weaknesses: | Small interior. Tough to rotate. Unsuitable for inclement weather or winds over 15 mph. Too long for many cars. | Must set up on soft surface. Not weather tight (except with separate fly). Tough to squeeze stiff material back into carrying case. | Small doorway limits size of telescope that fits inside. Sides not ripstop material. Translucent walls offer minimal benefit against light pollution. | Frame and poles block approx. 25° around the zenith (depending on height of observer) as well as four strips to the horizon. |
| Miscellaneous: | Weight: 20 pounds<br>Setup time: 12 min., 1 person<br>Cost: $398 – $445 | Weight: 32 pounds<br>Setup time: 5 min., 1 person<br>Cost: $375 | Weight: 30 pounds<br>Setup time: 8 min., 1 person<br>Cost: $385 | Weight: 14 pounds<br>Setup time: 1 min., 1 person<br>Cost: $319 |
| Address: | Clear Night Products<br>P.O. Box 721480<br>Berkley, MI 48072<br>Phone: (248) 547-2315<br>e-mail, barrycnp@earthlink.net<br>http://home.earthlink.net/~barrycnp | Kendrick Astro Instruments<br>2920 Dundas St. West<br>Toronto, Ontario, Canada M6P 1Y8<br>Phone: (416) 762-7946<br>Toll free: (800) 393-5456<br>Fax: (416) 762-2765<br>e-mail, kendrick@kendrick-ai.com<br>http://www.kendrick-ai.com | Kendrick Astro Instruments<br>2920 Dundas St. West<br>Toronto, Ontario, Canada M6P 1Y8<br>Phone: (416) 762-7946<br>Toll free: (800) 393-5456<br>Fax: (416) 762-2765<br>e-mail, kendrick@kendrick-ai.com<br>http://www.kendrick-ai.com | North Peace Outdoor Equipment<br>Suite 810<br>9707-110 ST. Capital Place<br>Edmonton, Alberta, Canada T5K 2L9<br>Toll free: (877) 687-3223<br>e-mail, mail@northpeace.com<br>http://www.TELUSPLAnet.net/public/northpc |

**1) TeleDome is very effective against light pollution; 2) Shelter-Dome opens on all four sides; 3) Observatory Tent offers separate sleeping and viewing areas; 4) Galileo features ripstop floors and walls.** All photos: Phil Harrington

widest. The smaller TeleDome measures 6' high, while the taller version is 6'6" at its peak. Both are designed for smaller, 3- to 8-inch telescopes.

While the TeleDome resembles a domed observatory, the Shelter-Dome gives observers a nearly unobstructed view of the sky. The Shelter-Dome measures 7' by 10' and is 6.5' high. It's made of fabric-reinforced vinyl. Setup was a little unwieldy at first, but soon became second nature. Remove it from its carrying case, unfold the sewn-in frame, and the Shelter-Dome blossoms before you. Just grab a mallet to drive five stakes into the ground.

The Shelter-Dome opens on all four sides, affording a clear view in every direction — except for minimal intrusion caused by the frame poles. Users can adjust the zippers on the completely opaque sides to block wind and light pollution. When fully opened, the sides drop to 36" off the ground; a larger door opening extends to the ground. Dobsonian owners looking toward the horizon will especially appreciate this latter feature.

Expect to use the Shelter-Dome as a fair-weather observatory. A rain fly is sold separately. It weathered wind gusts of 15 miles per hour.

One drawback to the Shelter-Dome is not in its use, but rather its after-use. Although everything breaks down very quickly, compressing the integral frame and stiff, plastic-coated material into its carrying case tests one's perseverance.

## Camping-Style Observatories

The Kendrick Observatory Tent and North Peace Galileo are adaptations of freestanding camping tents. Made from lightweight material and erected with segmented poles, these serve the dual purpose of providing shelter not only for your telescope, but also for you.

The Kendrick Observatory Tent was the first portable observatory on the market and still shows an ingenious design. It's really a modified, two-room camping tent, easy for one person to set up quickly. This veteran camper constructed it in only eight minutes the first time.

Once erected, the Observatory Tent has two rooms separated by a polyester wall. The smaller area (9' by 6') is for sleeping and storing supplies, while the larger area (9' by 9') is devoted to telescope space. The roof peaks at 6'6" but slopes off toward either end.

The D-shaped (30" by 50") door limits telescope use to nothing larger than a 10-inch reflector or possibly a 12-inch Schmidt-Cassegrain. Take care not to rip the unreinforced wall material. The Observatory Tent's floor, however, is made from plasticized ripstop polyester for extra strength. As a precaution, I suggest padding a tripod's feet to protect the flooring.

The Observatory Tent easily handled 20 mile-per-hour wind gusts. Its walls are not completely opaque, however, and diffused local light pollution.

North Peace teamed with the Royal Astronomical Society of Canada to modify two square dome tents into portable observatories: the Galileo (96" by 96" and 76" high in the center) and the Orion (84" by 84" and 60" high in the center). North Peace designed one of the simplest frames ever. Setup involves merely pushing the frame's central pivot upward like a giant umbrella until it locks in place. Voilà. In ten seconds, the tent was up.

Both of the North Peace astronomy tents are made of ripstop nylon, with a silver exterior and black interior. This combination is lightweight and provides an effective barrier against light pollution. It withstood winds up to 20 miles per hour.

The single-room Galileo tent has sides that zip open fully. It's large enough to house a 12.5-inch Newtonian reflector. Galileo's counterpart, the downscaled Orion, accommodates a low-riding 10-inch telescope. Again, pad the tripod's feet. Smaller telescopes work better with this structure, but even with all four doors open, the criss-crossing frame blocks certain angles.

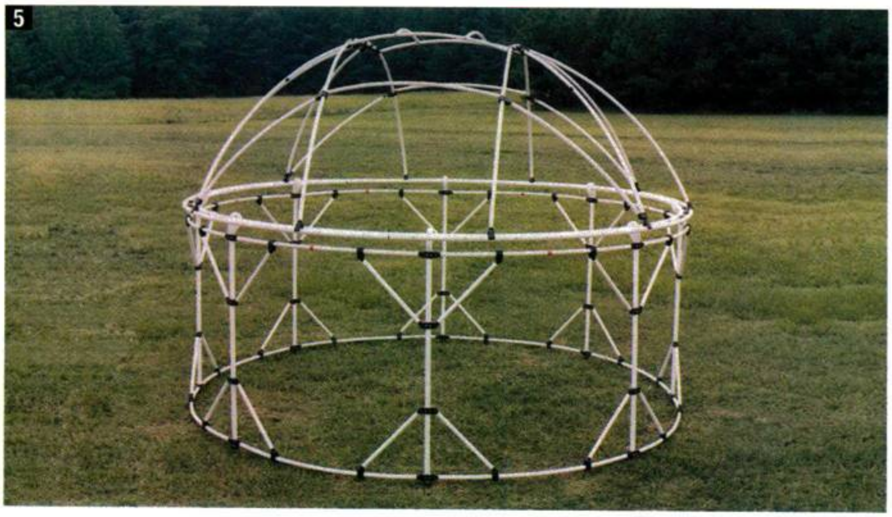
## Semipermanent Observatories

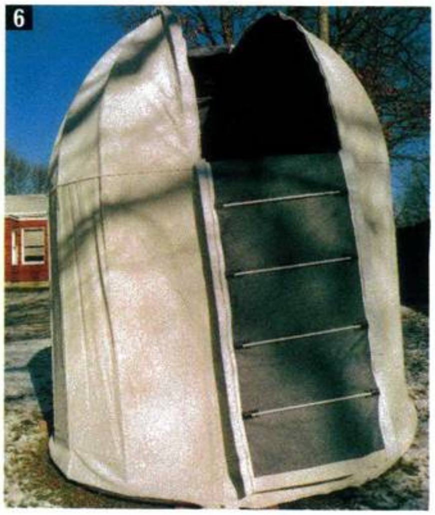
Those who seek a semipermanent observatory should consider a SkyTent or DarkSite Dome product. Both are substantial units designed to weather almost anything.

Although it was the largest observatory reviewed, the SkyTent was surprisingly easy to assemble. Clear instructions and clever construction ease setup. Snap together the framework of PVC pipes and then overlay the coated polyester fabric dome and wall.

My friend and I set it up in 25 minutes. Subsequently, I assembled and disassembled the SkyTent alone with little trouble, although shorter people might need help pulling the fabric over the top of the dome.

After you stake SkyTent's base firmly to the ground, you can rotate the PVC-framed dome smoothly and





**5) SkyTent's dome rotates easily along nylon guides;** David Phelps **6) DarkSite Domes' opaque walls are nearly weather-tight.** Phil Harrington

effortlessly through 360° by riding along its nylon guides.

Weatherwise, the dome's zipper has a generous overlap that seals with Velcro. Despite this, the SkyTent leaked a little after a heavy rain. Water infiltrated from the peak of the dome and could have dripped onto equipment. Still, the SkyTent fared very well in 25 mile-per-hour winds, as well as in a mid-January snow-and-ice storm.

Apart from the small leak, I found only two faults with the SkyTent. First, the vinyl-coated material is not completely opaque, making the white walls glow dimly from the glare of my neighbor's backyard spotlights. (An optional opaque blue interior for all models is now available.) Secondly, the metal zipper snagged more than once as I closed the aperture cover.

SkyTent offers several sizes and prices, from the 10' diameter by 7' high base model, tested here, to a 12' diameter by 10' high model for large Dobsonian telescopes. Other options include a removeable vinyl floor and chart and equipment tables that snap onto the PVC wall frame.

Like the SkyTent, the DarkSite Dome is also a semipermanent structure. It is constructed of a heavy, plastic-coated fabric set over a framework of fiberglass ribs supported on an aluminum base ring.

Of the tested observatories, this was by far the most difficult to assemble. The heavily-illustrated instruction manual took several reads. Even then, once I began, I immediately ran into trouble. Setup requires the user to position DarkSite's heavy, one-piece fabric body over the aluminum sidewall and fiberglass battens.

Assembling this unit took my friend and me 90 minutes; I couldn't have done it alone.

Although users must rotate the entire assembly when changing aim, it was relatively easy. An optional electric motor drive is available.

The dome's aperture closes with a plastic zipper and seals with Velcro. Like the SkyTent, its zipper snagged as I closed the dome. Stake this dome down when not in use — sustained 25 mile-per-hour winds moved it.

With the optional rain fly, the dome proved weather-tight except for a very minor leak near the bottom of the aperture after a heavy downpour. The leak did not affect the telescope.

Because of its size — 7'2" high and 6' in diameter — the DarkSite Dome is limited to small telescopes. Although it takes two to assemble, this is definitely a one-person observatory. And while the manufacturer states that the dome accommodates an 11-inch telescope, the interior seemed cramped with a tripod-mounted 4-inch refractor.

Stargazers tired of fighting the elements should consider buying a portable observatory. All models incorporate innovative features and allow for easy transport. When it comes to protection from wind or light pollution, you can take it with you.

## PROS AND CONS

### 5 Sky Tent

Strengths:
Easy to assemble. Effortless dome rotation. Large diameter.

Weaknesses:
Walls not completely opaque.

Miscellaneous:
Weight: 100 pounds (divided among three carrying cases).
Setup time: 25 min., 1 – 2 people
Cost: $1,795 to $2,995

Address:
SkyTent International
1289 N. Fordham Blvd.
Chapel Hill, NC 27514
Phone: (919) 401-2688
Fax: (919) 401-2689
Toll free: (877) SkyTent
e-mail, info@skytent.com
http://www.skytent.com

### 6 DarkSite Domes

Strengths:
Opaque walls very effective against light pollution.

Weaknesses:
Difficult assembly. Small diameter. Inconvenient rotation.

Miscellaneous:
Weight: 68 pounds (stored in one carrying case).
Setup time: 90 min., 2 people
Cost: $1,995

Address:
Tradewinds Company
2901T Avenue #7
Anacortes, WA 98221
Phone: (800) 526-3887
e-mail, jonn@cnw.com
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---

*Phil Harrington has studied the stars for more than 30 years. Visit his website at http://philharrington.homepage.com.*

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| SP56mm | 200 |
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| Super Wide 18 | 150 |
| Super Wide 24.5 | 180 |
| Super Wide 32 | 240 |
| Super Wide 40 | 300 |
| Ultra Wide 4.7 | 170 |
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| Ultra Wide 8.8 | 240 |
| Ultra Wide 14 | 300 |

**ETX Accy's:**

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| Case, hard 90 | 100 |
| Case, hard deluxe | 159 |
| Dew shield sliding | 32 |
| Easy-Mount | 59 |
| FlexFocus | 36 |
| FieldPod-Bogen | 159 |
| KwikFocus 90 | 32 |
| KwikFocus 125 | 32 |
| MegaPod | 239 |
| MotoFocus | 100 |
| MotoFocus/Dec | 170 |
| Power Package | 100 |
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| Piggyback 125 | 72 |
| Rigel Quickfinder | 40 |
| SCT accy adapt | 32 |
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| Solar filt-dlx-125 | 104 |
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| Visual back 1.25" | 32 |
| Wide-field/deluxe | 100 |

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| Ac adapter #541 | 42 |
| Car cord #607 | 28 |
| Computer cord #505 | 26 |
| Case,soft #765 | 42 |
| Case, hard #773 | 100 |
| Case, hard #774 | 100 |
| Case, hard #775 | 150 |
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| Elec focus #1247 | 124 |
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| Tripod- table #881 | 64 |
| Tripod- DlxEq #883 | 200 |
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| Barlow 2x #140 | 80 |
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| Compass #605 | 21 |

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| Epoch 2000 CD | 179 |
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| Flip-mirror #647 | 250 |
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| Finder 634-6x30 | 52 |
| Finder brkt-8x50 | 26 |
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| Lenshood 10" | 124 |
| Lenshood 12" | 174 |
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| Motor 531/532 | 104 |
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| Nebula 908 N | 90 |
| Nebula 908 O-III | 100 |
| Nebula 911 B | 100 |
| Nebula 911 N | 120 |

**Misc. Meade**

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| Pictor 208XT | 499 |
| Pictor 216XT | 699 |
| Pictor 416XTE | 1999 |
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| Prism 1.25" 45° | 45 |
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| 19mm | 240 |
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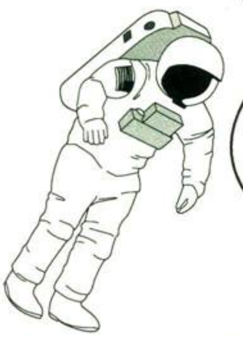

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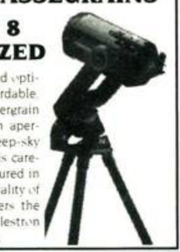

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# ask Astro

Buying a Telescope, Messier Objects, the Heaviest Stars

### Q: I want to buy a telescope, but I am bewildered by the choice of equipment. I am looking for a good scope to view planets and nebulae. I can spend up to $800. — *Gary Durham, Paget, Bermuda*

A: Start simply. First, learn the constellations with your unaided eyes. Then move on to a good pair of binoculars or a small (6- or 8-inch) Dobsonian reflecting telescope.

Binoculars provide a gentle transition between what you see with your eyes and a telescope. I recommend 7x50mm binoculars, which are good for night use because they gather enough light to see many faint objects and offer a wide field of view. Look for optics that are multicoated to enhance contrast and contain BAK-4 prisms to form sharp images over the whole field of view. Some binoculars within your $800 spending limit are rubberized and waterproof.

A Dobsonian telescope gives you the ability to see thousands of sky objects for a reasonable cost. The simple Dobsonian mount, which allows the telescope to move in two axes, doesn't require costly electronic and mechanical options. A 6x50mm finderscope is desirable. So is a rack-and-pinion focuser. Some manufacturers offer premium-quality Pyrex glass (which cools down faster for sharper views) or variable-friction bearings to hold the scope steady during gusts of wind.

A Dobsonian telescope with a 6-inch mirror typically retails for less than $400; an 8-inch might cost about $500; and a 10-inch Dob might sell for $800. (Larger mirrors gather more light and let you see fainter objects and greater detail in bright ones.) A feature such as a good finderscope might add $50 to $100 to the overall cost.

If you want technological sophistication rather than light-gathering power, consider computer-driven "go-to" scopes. These scopes offer databases crammed with thousands of targets. The scope's motorized drive can center on these targets with the touch of a button. Models even offer automated sky tours that show all the bright objects above the horizon for any given night. An $800 budget will buy a 3½-inch "go-to" telescope. You don't need thorough knowledge of the night sky to use "go-to" telescopes, but a 6- to 10-inch Dobsonian telescope will provide a vastly superior view of galaxies, star clusters, and nebulae. — *John Shibley, contributing editor*

**If you want detail and contrast in deep-sky objects, Dobsonian telescopes give you the most bang for the buck.** *Astronomy*

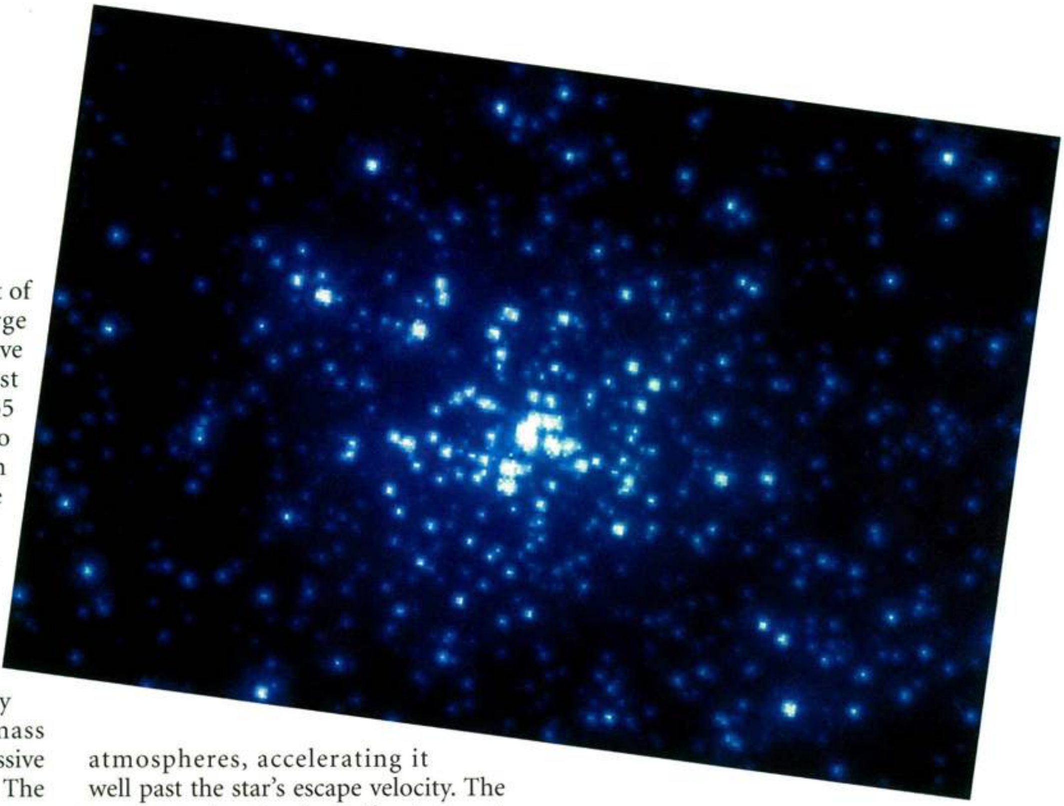
### Q: Which season features the most Messier objects in the evening sky and why? — *Paige Berkovitz, Eastchester, New York*

A: Summer is best for viewing Messier objects because the center of our galaxy rises into the evening sky, presenting an unparalleled collection of deep-sky targets. The second best season is spring, when the so-called "realm of the galaxies" is visible in the evening, showing viewers the greatest number of galaxies beyond the Milky Way in a single area of sky. — *David J. Eicher, managing editor*

### Q: What is the upper limit for stellar masses? — *Michael Butter, Hoyerswerda, Germany*

A: Astronomers have recently identified about a dozen stars whose masses have been estimated to exceed 120 solar masses. The famous star Eta Carinae and two other stars of its type, HD 5980 in the Small Magellanic Cloud and the Pistol Star, located near the galactic center, are thought to be of extremely high mass.

In addition to these three evolved stars, astronomers have found nine younger stars with masses above 120 solar masses. These stars reside in the



**The R136 cluster contains at least nine stellar superheavyweights.** Phil Massey (NOAO), Deidre Ann Hunter (Lowell Observatory), and NASA

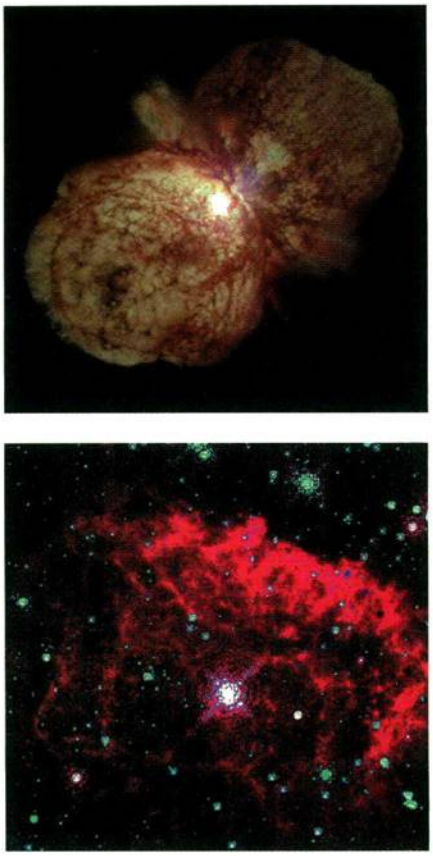
R136 cluster, which lies at the heart of the Tarantula Nebula in the Large Magellanic Cloud. Astronomers have conservatively estimated the most massive of these stars to contain 155 solar masses. We're beginning to realize that we have yet to find an observational limit to how massive a star can be.

What imposes the theoretical limit? We don't really know. British astronomer Arthur Eddington first proposed in 1926 that stars with more than 60 solar masses would be pulsationally unstable and would shed any mass higher than that amount. But massive stars are also extremely luminous. The sheer pressure of their light pushes on ionized atoms in the stars' outer atmospheres, accelerating it well past the star's escape velocity. The most massive stars have the strongest winds and might lose half their mass in a few million years. Recent computations suggest that the mass loss by these stellar winds will be as much as that lost from pulsational instabilities. Furthermore, improved calculation methods now place the theoretical stability limit as high as 440 solar masses.

Others argue that stellar masses are limited not by stability, but by how stars form. Astronomers once thought that the sheer pressure of starlight acting on infalling material might limit the mass of a forming star. But we now know that material does not simply fall onto a newly forming star but collects in a circumstellar disk, which slowly feeds matter onto the star. These disks may provide sufficient shielding to mitigate the effects of starlight pressure. Recent work suggests that mergers of large protostellar clumps of gas may be an important mechanism in star formation, in which case there may be no theoretical upper limit to how massive a star may form. — *Phil Massey, National Optical Astronomy Observatories*

**Eta Carinae (top) and the Pistol Star are two of the most massive stars in the Milky Way.**

Top: Jon Morse (University of Colorado), Kris Davidson (University of Minnesota), and NASA; Bottom: Don Figer (UCLA) and NASA



**Q: Are celestial objects in about the same location as they were the same night and same time the year before? — *Rachel Berkovitz, Eastchester, New York***

A: The short answer is yes. If you observe the sky tonight and again one year later, you won't notice any difference in star positions. In fact, you wouldn't notice any difference in 10 years' time, and you'd be hard-pressed to notice any change in 100 years.

But the gravitational pull of the sun and moon produce an effect called precession that causes the sky to change very slowly. During the 25,800-year precessional cycle, the position of Earth's axis in space traces out a 47°-wide circle on the sky. The effect causes stars to rise and set a few seconds later each year, on average, adding up to a total of 24 hours in one precessional cycle. In half that time, or 12,900 years, current winter constellations such as Orion will be visible in summer, while Sagittarius will appear in the winter sky. — *Richard Talcott, associate editor* A

**CONTACT INFO**

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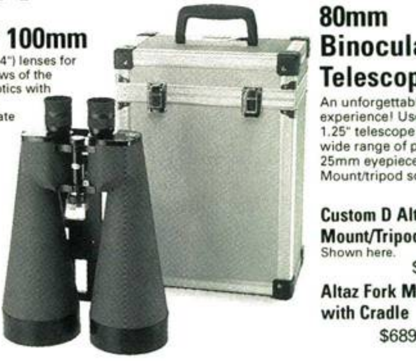

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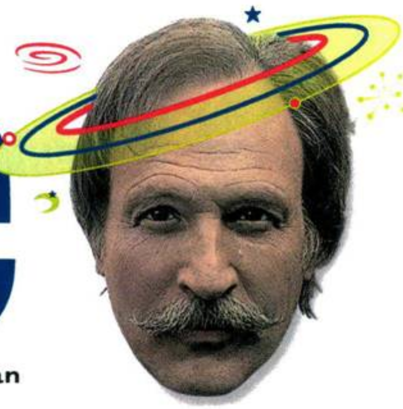
# strange Universe



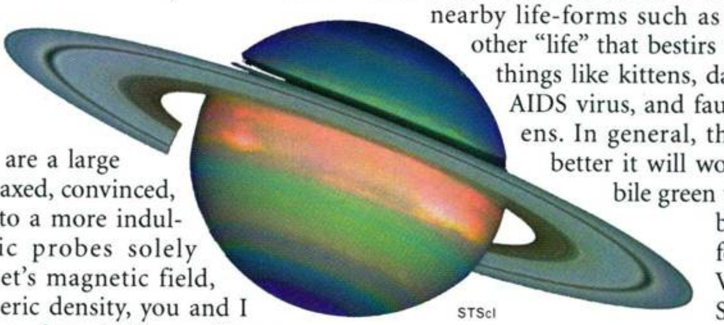
By Bob Berman

## Planet Schizophrenia

Depending on the situation, most of us show different sides of ourselves to different people. Surprise: Planets suffer the same split personality. But they are not born with this characteristic; we impose it on them.

Their "different strokes" arise out of a genuine need of NASA to maintain funding by "selling" planetary glamour. Now you and I find this odd because we are already drawn to planets and appreciate bland ones like Uranus as well as glitzy ones like Saturn. But there's a huge gap between how we astronomers regard them and how they're perceived by the public: they might as well be different worlds.

Given a choice, many people would not spend a dime to explore the universe beyond Earth. They think social problems rate funding priority and therefore consider it wasteful to throw billions of tax dollars to achieve who-knows-what in return. Since such people are a large constituency, they must be coaxed, convinced, even (dare we say) fooled into a more indulgent viewpoint. If robotic probes solely measured things like a planet's magnetic field, trace elements, and atmospheric density, you and I would be delighted because our knowledge would grow richer and more detailed. But the general public and Congress would say no way: There's no free launch.



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So continued planetary funding requires public relations — and glamour. Colorization is one way to add allure: Today, in the public mind, most planets are vividly tinted. Thanks to the publishing of enhanced and false-color images for the past few decades, almost everyone thinks of planets in Lava Lamp hues.

"Earthization" is another effective spin. Every proposed mission finds NASA declaring that the new probes "will teach us more about Earth." Well, in the sense that however remote, everything has some connection to Earth, it's true. As an example, Jupiter is an amazing place — intriguing beyond our comprehension and a worthwhile target several times over. Saying we're launching a Jupiter probe to learn about Earth is like a small town school group declaring they're going to visit New York "to learn more about Elmsville." Those of us fascinated by Jupiter are fully aware that we sent the Pioneers, Voyagers, and Galileo to learn about that planet, not ours.

Another sure-fire approach to win in Congress is to send scientists off to seek other life. It's a "given" that humans so yearn to discover life elsewhere; this underlying desire can be exploited to "green light" almost any mission.

If a planetary probe is laden with 20 instruments like plasma detectors that the public does not understand, NASA knows it must include a "water sensor" that will search for signs of life.

Except for a handful of favorite mammals, most people know very little about terrestrial life. They do not particularly care about varieties of moss in Malaysia; many don't like nearby life-forms such as neighbors. So it's not just other "life" that bestirs them, rather some life: cute things like kittens, dangerous life-forms like the AIDS virus, and fauna they will eat, like chickens. In general, the more titillating it is the better it will work. Scary triumphs; immobile green things don't. Microscopic — by far the most common form — doesn't work either. Venus's-flytraps qualify, South American fungi do not. We're a TV society inundated with action, violence, and special effects. Extraterrestrials had better be animated, cute, scary, or tasty if they're to grab more than their allotted 15 minutes of fame.

Would it really be the biggest event, ever, to find life on another world? I wonder. A few years back, a NASA team announced (in error, it now appears) that a meteorite from Mars contained a fossilized martian microbe. There it apparently stood: Life from Mars! It made headlines, but how many considered it an earthshaking event?

Of course, if newly found creatures buck the odds and are large enough to see as they swim merrily through Europa's oceans or the thick slush beneath Jupiter's cloud tops, so much the better. We're definitely intrigued by multicellular aliens, and the weirder the better. Earth has so many creatures that already look bizarre (such as squid) and so few that look cuddly (such as puppies). We can be confident that any large thing found elsewhere will appear satisfyingly alien. Whatever lacks a mammalian face is perceived as strange or repulsive; close-ups of insects or crustaceans fit the bill by seeming perfectly extraterrestrial. Japanese moviemakers were on to that years ago. There's probably an alien-to-cuddly ratio of 10,000-to-1 right here on Earth. Extrapolating, there are undoubtedly more weird squid-things than puppy-things in the cosmos, assuring the all-time biggest headline to the cuddly.

Point is: What we learn from the media reflects simplified and often sensationalized coverage. This stems partly from public-relations packages and briefings distributed by NASA, largely designed for the ingestion of a popular audience. That's why when people discuss the latest space probe, they're more likely to say, "I've heard it's looking for life" than "Wouldn't it be odd if it detects no argon?"

Don't bother correcting them. ("No, Uncle Fred, actually the probe contains no experiment that could find life.") Just realize that what most people think is miles from what's really happening.

Spacecraft experiments reflect a potpourri of diverse interests. Some researchers care about magnetospheres, others are interested in geology, others are looking at chemistry and searching out unique isotopic ratios. Planets are the final frontier for hands-on researchers in wonderfully nonterrestrial environments. There's so much to learn, and no one field is better than another. The simple truth is that the brilliant dot in the eastern sky these mornings is an impossibly complex, dynamic world so unlike Earth, it offers an Alice-in-Wonderland adventure of the strangest order.

The popular public persona of planets as vivid, colorful worlds brimming with life-potential, ripe for future terraforming, and full of promise for 21st-century colonization may be fanciful, but the dream keeps rockets flying. We with backyard telescopes have our own gratifying dreams and images. Our planets may not be as colorful, nor as welcome to visit. But they're every bit as exciting. ■

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*Bob Berman's Strange Universe column is a new montly feature in* Astronomy *magazine. He also wrote "Desperately Seeking Dark," a guide to dark-sky observing on page 82. Berman is the author of several books on astronomy, including* Secrets of the Night Sky: The Most Amazing things in the Universe You Can See with the Naked Eye.

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Meade 5" ETX-125EC
**$895**

At the time this was written (5/2), we had 155 ETX-125EC 5" Maksutov-Cassegrains in stock, with 400 more scheduled for delivery before the end of the year.

With more than 200 sold during the first three months of this year, the ETX-125EC is one of our best-selling scopes.

And we don't just have ETX scopes. We have Autostar computers, cases, tripods, eyepieces, electric focusers, filters, camera adapters, and more. If it's a Meade accessory for the ETX-125EC – or any Meade telescope – chances are good we have it in stock.

## Special Celestron 8" Dob package price!

Celestron 8" Dob package
**$???**

We've perked up more than 50 of the 8" Celestron Dobsonian reflectors we have in stock by adding a Telrad finder, a 10mm SMA eyepiece (it already comes with a 25mm), and a 2x Barlow. Then we priced the entire package at . . . sorry, but you'll have to call us at (800) 422-7876 to discover our low price – the lowest in the country for a Celestron Dob with all these extras.

## 3-day air shipping at no extra cost!

We ship by three-day air UPS from our warehouse to our East and West Coast customers at no extra charge above our regular shipping (except for scope cases, Dobsonians, dewshields, and a few other big items). No matter where you live in the 48 continental United States, your order should arrive by the third business day after we ship. UPS can't guarantee 3-day delivery in case of bad weather or during peak seasons, so UPS service guarantees do not apply to this limited time free upgrade if shipments are delayed.

## A fully-computerized *8"* go-to scope for only $1899? *Amazing!*

You read that price right. Only $1899 for a fully-computerized go-to 8" telescope. Even better, the new **Celestron NexStar 8** can be powered by AA flashlight batteries. You're never tied down to an AC power outlet or a heavy rechargeable battery pack to use your scope.

The **NexStar 8** puts sharp, bright f/10 Schmidt-Cassegrain optics into a sleek metal housing that brings go-to scopes into the 21st century in style!

Celestron NexStar 8,
**$1899**

The NexStar's standard computer hand control stores in a recess in the scope's rigid single metal fork arm (and operates while stored there, as well as when it's undocked and handheld at the end of its coiled cord). The computer quietly moves the AA battery-powered NexStar at a fast 6.5° per second to 18,473 stars and deep space objects, all of the non-stellar objects that you can see in a scope this size. The computer also takes you on guided tours of the most spectacular deep sky objects visible on the night you observe. Standard equipment includes electric slow motion controls; a NexStar Plössl eyepiece; and a non-magnifying long eye relief Star Pointer red dot finder that's ideal for eyeglass wearers. An AC adapter is standard, not a costly option.

You can experience the heavens only a few days after you order a **NexStar 8** from ***astronomics!*** With 59 in stock on 5/2 and over 300 scheduled for delivery over the next six months, chances are good we have one in stock for you.

## Our free catalog helps you pick the right Meade, Celestron, Questar, Takahashi, or TeleVue scope.

For detailed information on individual products, visit our Web site. Or call us at (405) 364-0858, or e-mail us, for your *free* copy of our catalog AST. It covers all the scopes and accessories we stock – from Bushnell, Canon, Celestron, JMI, Lumicon, Meade, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute phone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

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Toll-Free Order Line: **(800) 422-7876**
Catalogs/Questions/Advice: **(405) 364-0858**

# We'll sell you the *right* telescope.

## The right scope might be a TeleVue.

TeleVue TV-85, in stock, **$1995**

Hardly a week goes by that TeleVue doesn't send us copies of new warranty cards filled with glowing comments that our customers have written about the new TeleVue scopes they bought from us. But we don't need to be reassured about TeleVue quality. We've come to expect nothing but praise for TeleVue, which is why we stock them in depth. We had 36 people-pleasing TeleVue scopes in stock and 45 more on order at the time this was written (5/2).

**Pronto**, **Ranger**, **TV-85**, **TV-101**, the new **TV-102** optical tube, **Renaissance** – all are built to uncompromisingly high optical and mechanical standards. Their short focal lengths give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power observing, all without losing optical quality (one test report said they used an amazing 89x per inch of aperture on TeleVue's least expensive model, the Ranger).

In addition to scopes, we also stock all the TeleVue eyepieces, Barlows, and accessories in depth. Be it a Plössl, Nagler, Radian, Powermate, Panoptic, tunable top Paracorr, Gibraltar or Tele-Pod mount, Qwik-Point finder, and more, if it's a TeleVue product, the chances are good we have it in stock.

## CCD? We carry Meade *and* SBIG.

Since we stock almost all available models of both Meade and SBIG CCD cameras, autoguiders, and accessories, chances are good you won't have to wait to get the camera of your choice. Here are just a few of the cameras we keep in stock and their prices.

| | |
|---|---|
| **Meade 201XT** autoguider | \$395$^{00}$ |
| **Meade 216XT** 16-bit camera | 695$^{00}$ |
| **Meade 416XTE** camera/guider package | 1995$^{00}$ |
| **SBIG ST-237** track/accumulate camera | 1195$^{00}$ |
| **SBIG ST-7E** self-guiding camera | 2950$^{00}$ |
| **SBIG ST-8E** self-guiding camera | 7350$^{00}$ |
| **SBIG STV** digital video camera/guider | 1595$^{00}$ |
| **SBIG STVD** digital video w/LCD screen | 1995$^{00}$ |

## It might be a Questar.

For many people, the thought of a 3.5" scope that *starts* at $3399 is enough to curl their toes. But for those who want the best small telescope made, $3399 is a bargain.

Questar
3.5"
Standard
$3399

Solar filters for eyepiece and finder, built-in Barlow, two ultra-premium eyepieces, a velvet-lined hard case, a star chart on the slide-on lens shade with a Moon map beneath – all are standard on a Questar . . . and unavailable from the competition.

Want a Questar, the premier portable telescope? We stock them.

## We'll make you an offer you can't refuse on a CM1400.

Celestron CM1400

We made another special buy on a large quantity of Celestron's premium 14" CM1400 Schmidt-Cassegrain German equatorial mount telescopes. The normal retail on the CM1400 is $5299. But, once again, our price is too low to print. You'll have to call us at (800) 422-7876 to discover the actual price. While quantities are large, they're not infinite, so don't miss out.

## LER eyepieces from Takahashi.

7mm to 50mm Takahashi eyepieces

Takahashi LER (long eye relief) eyepieces have a well-deserved reputation for sharpness – after all, they're used on scopes that *start* at $4500 for a 4". And serious planetary photographers love the orthos for eyepiece projection.

| | |
|---|---|
| **5mm or 7mm** LER 1.25" | \$175$^{00}$ |
| **12.5mm, 18mm, or 24mm** LER 1.25" | 165$^{00}$ |
| **30mm** LER 1.25" | 185$^{00}$ |
| **50mm** LER 2" | 349$^{00}$ |
| **2.9, 4, 5, 7, 9, 18, 25mm** ortho 0.965" | 139$^{50}$ |

## Celestron NexStar 5? We have 82 in stock!

At the time this was written (5/2), we had 82 Celestron NexStar 5" f/10 go-to computerized Schmidt-Cassegrains in stock for immediate shipment.

The NexStar 5 has the same built-in 18,473-object database computer as the NexStar 8 on the previous page. It has the same penlight-battery DC operation, the same sleek 21st century styling, the same standard equipment AC adapter and eyeglass-friendly Star Pointer finder. And it's all in a package that's supremely portable and user-friendly.

NexStar 5
$1199

## It could be a Takahashi refractor.

While many people swear *at* the long delivery times quoted by some premium refractor manufacturers, most knowledgeable astronomers swear *by* the unsurpassed optical quality and fast delivery of the Takahashi apochromatic refractors we keep in stock.

From the 2.4" **FS-60C** to the 5" **FS-128**, we stock Takahashi fluorite/special dispersion glass apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast*. We can also special order larger scopes with 1-3 month delivery times. Why wait for 1-3 *years* to get your apo refractor or mount from another manufacturer? You can be usually be viewing through a truly fine Takahashi apo only a few short days after you order from us.

Takahashi FS-102UH (4" f/8 fluorite/SD on EM-10USD mount)

We stock complete Takahashi apo scopes on USD mounts with dual-axis 50x sidereal slewing, as well as apochromatic optical tubes to install on your own mount.

We also stock the amazing Takahashi **FSQ-106** 4" dual fluorite lens 4-element f/5 apo refractor. It's both a superb visual scope and a 4" focuser medium format astrograph. We had 7 in stock as this was written on 5/4.

Also in stock is the unique Takahashi **CN-212H** 8.3" reflector that converts from an f/12.4 classical Cassegrain reflector to a very fast f/3.9 Newtonian for both high contrast visual observing and wide field astrophotography.

If you want an apo, and want it *now*, it's Takahashi from ***astronomics***.

> I can't thank you enough for your wonderful service! The telescope I bought from you a few months ago is better than I ever hoped for, and your advice was outstanding in meeting my needs and my budget. I was especially impressed when I called about ordering a set of binoculars: your staff person actually was able to get me a better set of binoculars at a lower price than the ones I originally had in mind. That kind of care for the customer as a person, rather than just another customer, is absolutely wonderful.
>
> **Customer Quote of the Month #101**

## Or maybe it's this 8" *astronomics* exclusive that saves you over 50%!

~~$2868 list~~
$1349

CELESTRON

Celestron C8 Special Edition, an astronomics exclusive (shown with optional dec motor)

Our 8" Celestron **C8 Special Edition** is built for us by Celestron, exclusively to our specifications. We have 43 available. *No other telescope dealer has it.*

The **C8 Special Edition** consists of an 8" Celestar Schmidt-Cassegrain telescope with sharp Starbright multicoated f/10 optics and all the most-wanted features and options. Big setting circles, dust covers, and manual slow motion controls are standard equipment. Not only do you get an accurate sidereal rate DC drive that's powered by an ordinary 9-volt transistor radio battery for true cordless operation in the field (battery included) *but you also get separate power adapters for both 110 Volt household AC power in the backyard and 12 Volt DC car battery use out at dark sky observing sites.*

You get a separate wedge with azimuth adjuster. The *adjustable height* heavy duty metal tripod has 2" diameter steel legs. The finder is a big 9 x 50mm. You get *two* Celestron Plössl eyepieces – a 26mm (78x) *and* a 10mm (203x). Both have removable rubber eyeguards, an ***astronomics*** exclusive. You also get a Moon filter and a CD-ROM of Celestron's TheSky Level 1 star charting software for your PC.

You won't find this exclusive package of the most-wanted features and accessories on any other Celestron telescope. And you won't find any other telescope dealer with anything approaching this unique Celestron package at this low price. ***It's an astronomics exclusive!***

## A Nikon zoom for $333 below dealer cost!

This 40mm XL is Nikon's best zoom binocular. 8x to 16x at a finger's touch. $1264.95 list. Regular dealer cost is $632. We bought every one Nikon had in this country. You won't find a lower price.

## We stock Pentax eyepieces.

From 5.2mm to 40mm, we stock the Pentax wide field (55° to 65°) long eye relief (20mm) ED glass eyepieces. Premium eyepieces . . . at unpremium prices.

| | |
|---|---|
| **5.2 or 7mm** 1.25" 65° | \$259$^{00}$ |
| **10.5, 14, or 21mm** 1.25" 65° | 249$^{00}$ |
| **28mm** 1.25" 55° | 239$^{00}$ |
| **40mm** 2" 65° | 259$^{00}$ |

**24-Hour FAX line: (405) 447-3337     Our e-mail address: questions@astronomics.com**

**Our multiple award-winning Internet address: www.astronomics.com**

**Our phone lines are open 10 to 7 CST, Monday thru Friday, and most Saturdays from 12 to 5.**

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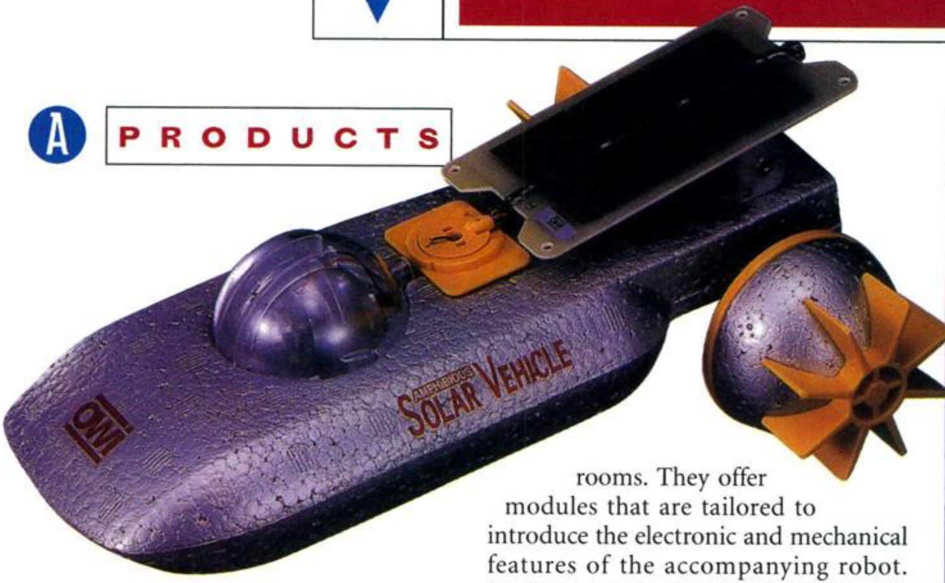
No credit card surcharge. $5.95 minimum freight. All returns less freight. Restocking fees apply to returns for credit and to merchandise returned used or damaged.

# PRODUCTS



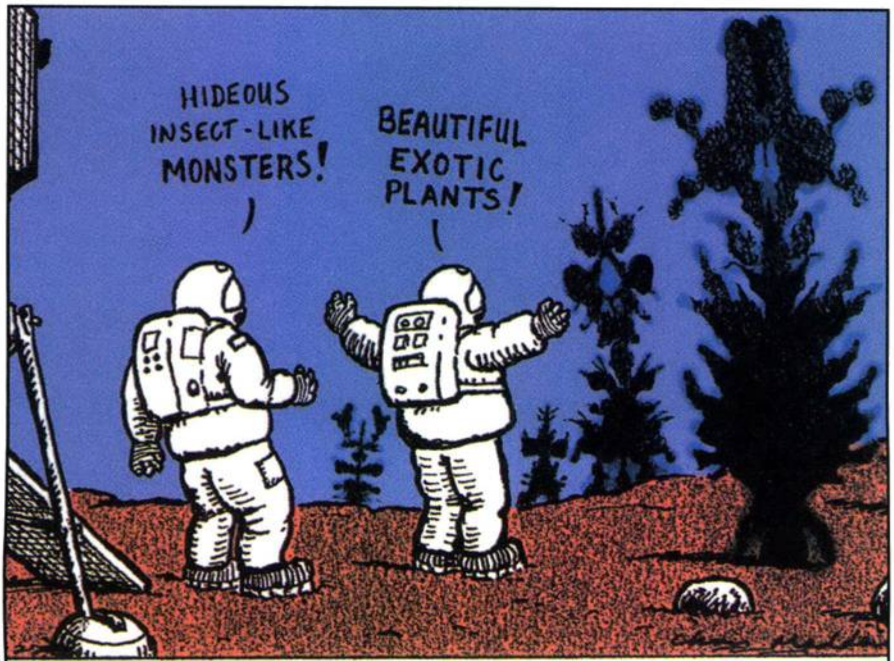
## Robot Kits

▶ If you're looking for educational summer projects to occupy your budding scientist's time, try one of OWI's robot kits. Three levels (beginner, intermediate, and advanced) offer challenges to a broad age range (grade school to adult). Beginner kits require basic assembly using fine motor skills and household tools. Intermediate kits are recommended for ages 10 and up, while advanced kits must have their circuit boards and mechanical assemblies soldered.

OWI also offers educational kits used primarily in science centers and classrooms. They offer modules that are tailored to introduce the electronic and mechanical features of the accompanying robot. Students can also join the "MAKIT with OWIKIT" club. Membership offers free repairs, new product updates, and official membership items.

The Amphibious Solar Vehicle (pictured) is powered by any intense light. With a flip of the switch (solar or battery), the car is energized.

*OWI Robot Kits, 17141 Kingsview Ave., Carson, CA 90746; phone toll free (U.S. only), (877) 515-6660; fax, (310) 515-1606; e-mail; owi@ix.netcom.com; website, http://owirobot.com.* Amphibious Solar Vehicle: *$39.95.*


HIDEOUS INSECT-LIKE MONSTERS!
BEAUTIFUL EXOTIC PLANTS!

On the planet of the ink-blot beings.

Chris Madden

DFM ENGINEERING, INC.
SERIAL PORT
MAN CONTROL
POWER
FILTER WHEEL MODEL FW-82

## A Filtered View

▶ DFM Engineering offers a standard filter wheel that holds 50mm diameter or 2-inch diameter filters in one of eight positions — adapters allow the use of 1.25-inch threaded mount filters as well as other sizes. The wheel may be controlled using DFM's Telescope Control System, The Sky, or through your telescope's computer. An RS-232C interface connects the wheel to the computer, while the low-power DC motor operates from 12 volts DC, 115 VAC, or 220 VAC. The FW-82 has a low profile (one-inch thick) and weighs only four pounds without filters.

*DFM Engineering, 1035 Delaware Ave. Unit D, Longmont, CO 80501; phone, (303) 443-2031; website, http://www.dfmengineering.com.* FW-82: *$1,995.*

# BOOKS

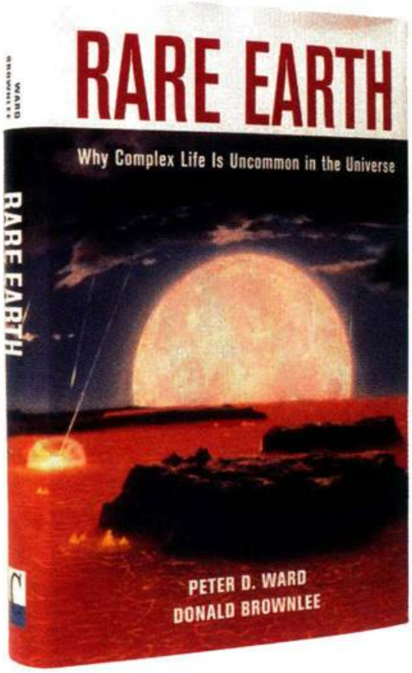
### Rare Earth: Why Complex Life is Uncommon in the Universe

Peter D. Ward and Donald Brownlee, 333 pages, Copernicus Books/Springer, New York, 2000; ISBN 0-387-98701-0; hardcover, $27.50.

▶ With 200 billion stars in the Milky Way Galaxy, it's easy to believe there might be billions of planets with complex life. Not so fast, counter two University of Washington scientists in their new book *Rare Earth*. Paleontologist Peter Ward and astronomer Donald Brownlee agree with extraterrestrial-life optimists that say simple microbial life is common throughout the universe. But they diverge from that viewpoint when it comes to complex life (i.e. animals and higher plants). "In this book we will argue that not only intelligent life, but even the simplest of animal life, is exceedingly rare in our galaxy and in the universe."

The authors maintain that complex life can only exist in a narrow range of environments. They devote most of their book to a discussion of why Earth offers unusually favorable conditions and why these conditions are unlikely to prevail on all but a few precious worlds. Complex life needs a Jupiter-size planet in the system to drive away asteroids and comets. Hospitable planets need plate tectonics to regulate climate and isolate populations for rapid speciation. Earth-sized planets need a large moon to stabilize the tilt of the rotation axis. Planets can't be too large or too small, and they need to be at just the right distance from their stars. Stars need to be rich in heavy elements, and they can't be too close or too far from the center of the galaxy. This list goes on.

While the authors make a reasonably persuasive case, I was disappointed by a number of careless factual errors. In the preface, they failed to correctly spell the names of two prominent astronomers who helped them with the book: Geoff Marcy (they spelled it "Marcey") and Kevin Zahnle ("Zahnlee"). On page 84, the authors claim "the genes in a large animal number in the millions." In actuality, the number is closer to 100,000. On page 163, they state that Mercury and Venus always present the same face toward the sun. That's not true. While these individual errors are not central to their argument, they create doubts over credibility. What other factual errors would actually undermine their Rare Earth Hypothesis?



I found some of the arguments, such as the need for a Jupiter-like planet for sophisticated life, more convincing than others. For example, scientists have no way of knowing how common plate tectonics might be on other "terrestrial" planets. There is some evidence that both Mars and Venus experienced plate tectonics in the distant past. Even if plate tectonics is rare, some unknown mechanism could fulfill the same role. There simply isn't enough data to justify blanket statements concerning billions of terrestrial planets.

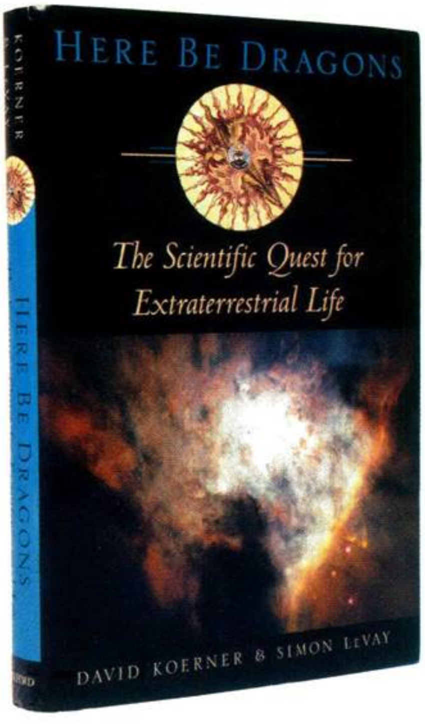
The fact is, scientists on both sides can summon apparently convincing arguments until they're blue in the face. But the existence or nonexistence of extraterrestrial life will only be proven by observation of other worlds, not by extrapolating what we know about Earth to the cosmos. The authors, to their credit, recognize this fact. They admit their Rare Earth Hypothesis is an "unproven supposition." And never do they call for a cessation of efforts to detect extraterrestrial life. In a chapter titled "Testing the Rare Earth Hypothesis," they describe planetary missions, large space-borne telescopes, and other experiments (including SETI) that could bolster or refute their conclusions.

You can bet that astronomers involved in the search for extraterrestrial life will not buy Ward and Brownlee's argument. But whether one agrees with the book or not, at least it provides a comprehensive overview of current developments in astrobiology and the history of life on Earth. In my view, the authors marshal enough valid arguments to cast doubt on Saganesque optimism that the universe is brimming with complex and even intelligent extraterrestrial life. But we really don't know who or what is out there, so let's keep searching. — *Robert Naeye*

### Here Be Dragons: The Scientific Quest for Extraterrestrial Life

David Koerner and Simon LeVay, 264 pages, Oxford University Press, New York, 2000; ISBN 0-19-512852-4; hardcover, $27.50.

▶ One has to feel sympathy for University of Pennsylvania astronomer David Koerner and former Salk Institute biologist Simon LeVay. The two have coauthored a superb new book about extraterrestrial life. But they had the misfortune of seeing their book, *Here*


HERE BE DRAGONS
The Scientific Quest for Extraterrestrial Life
DAVID KOERNER & SIMON LEVAY
KOERNER
HERE BE DRAGONS

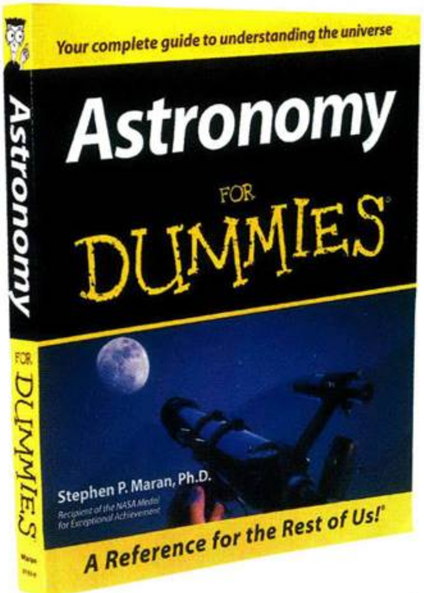
*Be Dragons,* released at nearly the same time as *Rare Earth. Here Be Dragons* may be overshadowed by the more controversial *Rare Earth.*

Where *Rare Earth* argues a point of view, *Here Be Dragons* takes a more agnostic stance on the question of extraterrestrial life. "After listening to all the arguments of the 'optimists' and the 'pessimists,' we can't help but focus on the magnitude of our ignorance," write Koerner and LeVay. The authors devote chapters to the topics one would expect: speculations on the origin of life on Earth, searches for life in the solar system, the formation and evolution of stars and planetary systems, SETI, UFOs, etc. Authoritative and clearly written, *Here Be Dragons* offers a more balanced alternative to those who might be turned off by the skepticism of *Rare Earth.*

### Astronomy for Dummies

Stephen P. Maran, 310 pages, IDG Books, Foster City, California, 1999; ISBN 0-7645-5155-8; paperback, $19.99.

▶ Another in the long line of "Dummies" books, *Astronomy For Dummies,* by Stephen P. Maran, an astronomer at NASA's Goddard Space Flight Center and a member of *Astronomy*'s editorial advisory board, treats the reader like anything but a dummy. Instead, it serves as a friendly introduction to a fascinating but often intimidating science and hobby. Think of this book as a favorite teacher who gives unconditional encouragement to any student attempting to learn.

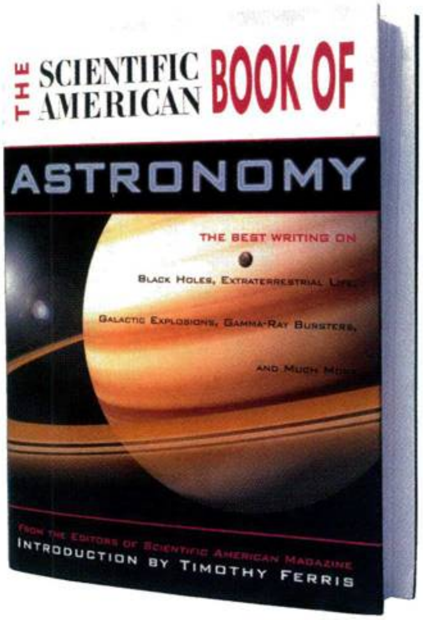

Your complete guide to understanding the universe
Astronomy
FOR
DUMMIES
Stephen P. Maran, Ph.D.
A Reference for the Rest of Us!

*Astronomy For Dummies* gives a common-sense approach to a subject. Questions are answered in plain language with just enough humor to relax any reader on the verge of self-doubt. Even Einstein didn't catch on to everything immediately.

### The Scientific American Book of Astronomy

384 pages, Lyons Press, New York, 1999; ISBN 1-55821-966-8; hardcover, $35.

▶ Thirty-two essays culled from the pages of *Scientific American* compose this new release. Seven sections, from "Rays, Waves, and Particles" to "Galaxies" to "Technology," cover the major categories of astronomy. Most of the chapters were written by leaders in their respective fields. Andrei Linde penned the chapter titled "The Self-Reproducing Inflationary Universe"; Jane Luu and David Jewitt composed "The Kuiper Belt"; and Shannon Lucid authored "Six Months on Mir." Although the scientist-authors work and think at an advanced level, the text is surprisingly readable. Eight centrally located color plates and some sparse graphs and drawings help to illuminate the text. The biggest drawback of the book is that four of the essays are more than 15 years old.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THE BEST WRITING ON
BLACK HOLES, EXTRATERRESTRIAL LIFE,
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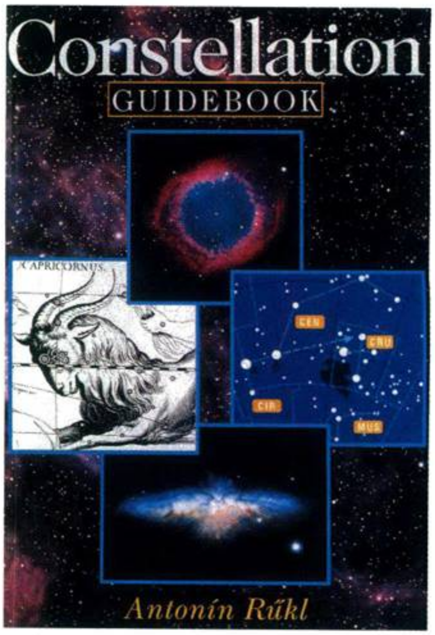
Constellation
GUIDEBOOK
CAPRICORNUS
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Antonín Rükl

### Constellation Guidebook

Antonín Rükl, 224 pages, Sterling Publishing Co., New York, 1999; ISBN 0-8069-3979-6; paperback, $14.95.

▶ This glossy-paged book begins with an overview on observing and its many associated terms. The book allots two pages to each constellation, which are listed alphabetically. Each constellation page includes a star map, an image of the Big Dipper used for scale, and in some cases drawings of notable objects within the constellation or an illustration of the mythological item after which the constellation is named. The constellation pages have an easy-reference color-coding scheme. Northern Hemisphere constellations have a red tag, southern ones have a yellow tag, and those that lie along the celestial equator are tagged in orange.

### PRODUCT INFO

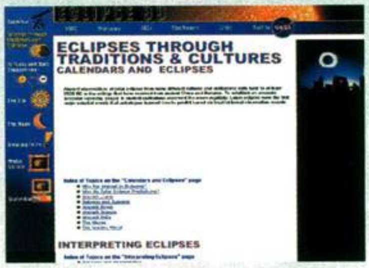
Suppliers should send announcements and color photographs to Star Stuff, P.O. Box 1612, Waukesha, WI 53187, or e-mail starstuff@astronomy.com. *Astronomy* assumes no responsibility for the product information supplied by manufacturers. Prices are retail and subject to change without notice. Check *Astronomy*'s website for further product updates — http://www.astronomy.com

## The Webweaver Picks

The following websites offer a wide range of information about total solar eclipses (also see "Diving into Darkest Africa," page 76).

NASA / GODDARD SPACE FLIGHT CENTER
Eclipse
Eclipse Home Page

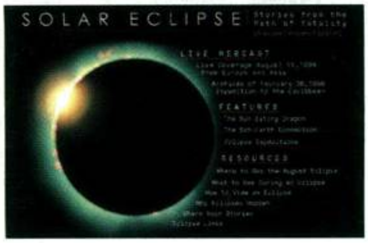
**Fred Espenak's Eclipse Page**
http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html


ECLIPSES THROUGH TRADITIONS & CULTURES
CALENDARS AND ECLIPSES
INTERPRETING ECLIPSES

**Eclipses through Traditions and Cultures**
http://www.eclipse99.nasa.gov/pages/traditions.html

Astronomical Applications
Upcoming & Recent Eclipses of the Sun and Moon

**Upcoming Eclipses of the Sun and Moon**
http://aa.usno.navy.mil/AA/data/docs/UpcomingEclipses.html


SOLAR ECLIPSE
LIVE WEBCAST
FEATURES
RESOURCES

**Exploratorium: Solar Eclipses Stories from the Path of Totality**
http://www.exploratorium.edu/eclipse/

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AVAILABLE SEPTEMBER 2000

The Ultimate Tool For Skywatching!

**Explore The Universe 2001** is packed with valuable tips, features, and information to help you see more of the universe than ever before, including:

- **A Detailed, Illustrated Month-By-Month Guide To The Sky:** listing all major astronomical events for the year 2001.
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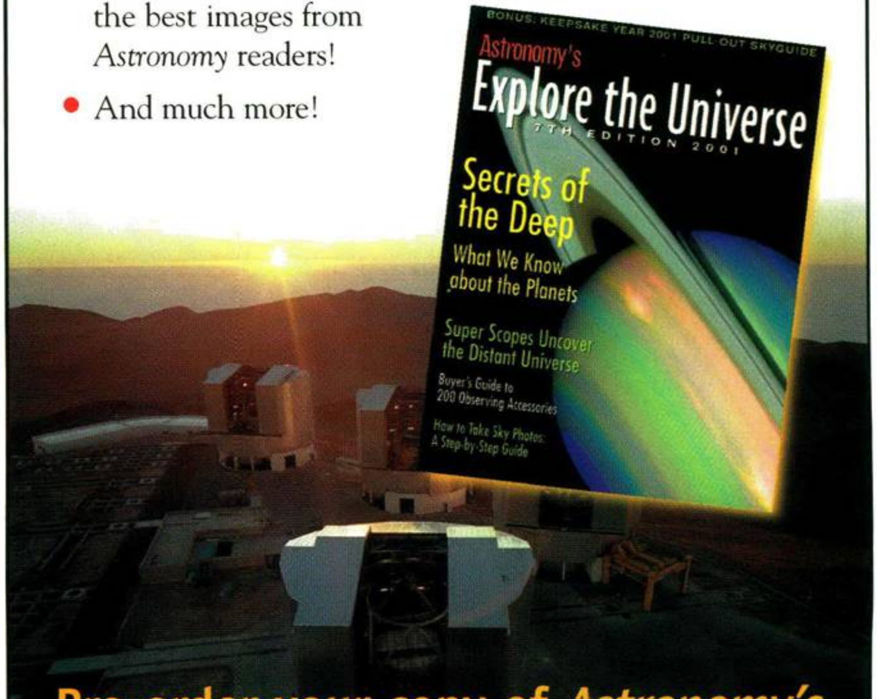
- **Plus Remarkable Full-Color Photography:** including the best images from *Astronomy* readers!
- And much more!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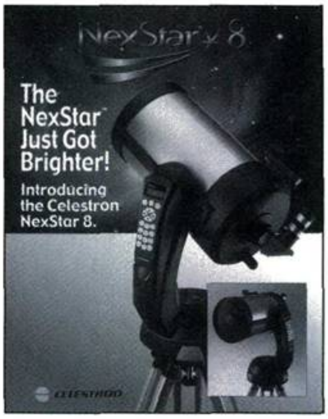
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Introducing the Celestron NexStar 8.
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This scope has all the proven features of the NexStar 5, with more than twice the light grasp.

The Go-To Computer system contains 18,000+ objects. The NexStar 8 comes with a/c adapter or runs off 8 AA batteries (not included). All for an amazing $1899 plus shipping.

## Other Celestron Telescopes at Lumicon

| | |
|---|---|
| NexStar 5 | $1199 |
| Ultima 2000 | $2699 |
| Celestar Deluxe | $1699 |
| Celestar | $1099 |
| CM 1100– 11" SCT | $3199 |
| Starhopper 8" Dob | $429 |
| Starhopper 6" Dob | $339 |
| C102-HD 4" Refractor | $499 |
| FS114 Deluxe | $299 |
| CR150 6" f/8 Refractor (NEW) | $1199 |

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The G8 & G11 Mounts are among the finest mounts made in America. Both have dual-axis drive with periodic error correction built in. The GM8 can carry 30 lbs. of equipment, the G11 can carry *60 lbs. of equipment.*

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|---|---|
| GM8 Mount with Tripod | $1499 |
| G11 MountwithTripod | $1899 |

Other fine Losmandy accessories available.

## LUMICON FILTERS - BEST IN THE WORLD BUT WHICH FILTER TO BUY?

LUMICON H-BETA
LUMICON OIII
LUMICON UHC
LUMICON DEEP-SKY

**Lumicon Deep Sky Filters** follow the classic broad band curve but offer the highest transmission of nebula lines of any such filter available. Lumicon Deep Sky filters block mercury and sodium vapor lamp emissions while letting thru all other parts of the spectrum. Deep Sky Filters are most useful for astrophotography (color & b&w) and CCD work. Deep Sky Filters are also useful visually, nebula offering the best contrast gain but galaxies, star clusters and dusty comets are also slightly enhanced.

| | |
|---|---|
| **1.25" Deep Sky Filter** (fits most 1.25" eyepieces) | $99.50 |
| **48mm Deep Sky Filter** (fits 2" eyepieces and Lumicon accessories) | $199.50 |
| **Visual Back Deep Sky Filter** (fits in series on back threads of SCT'S) | $199.50 |
| **2" Deep Sky Filter** (fits 2" eyepieces and T-threaded accessories) | $199.50 |
| **72mm Deep Sky** Filter (for the front of large telephoto lenses*) | $399.50 |

*step rings for other sizes available.

**Lumicon Ultra High Contrast Filters** have a narrow band pass that lets thru the two oxygen III and the hydrogen beta lines while blocking the remaining visual spectrum. The resulting filter yields high contrast views of all types of nebula. It is best used visually with any telescope of f/6 or longer focal ratio. The Ultra High Contrast Filter is not for photography.

| | |
|---|---|
| **1.25" Ultra High Contrast Filter** (fits most 1.25" eyepieces) | $99.50 |
| **48mm Ultra High Contrast Filter** (fits 2" eyepieces and Lumicon accessories) | $199.50 |
| **Visual Back Ultra High Contrast Filter** (fits in series on back threads of SCT'S) | $199.50 |

**Lumicon Oxygen III** filters isolate just the two oxygen III lines of the spectrum and block the remaining visual spectrum. The Oxygen III filter yields the maximum contrast gain possible on planetary nebula and most emission nebula. Views of the Veil Nebula and others with this filter are beyond words. The Lumicon Oxygen III Filter is for visual use only and is best suited for 6" and larger aperture telescopes with focal ratio of f/10 or faster.

| | |
|---|---|
| **1.25" Oxygen III Filter** (fits most 1.25" eyepieces) | $99.50 |
| **48mm Oxygen III Filter** (fits 2" eyepieces and Lumicon accessories) | $199.50 |
| **Visual Back Oxygen III Filter** (fits in series on back threads of SCT'S) | $199.50 |

**Lumicon Hydrogen Beta Filters** isolate just the hydrogen beta line of the spectrum and block the remaining visual spectrum. The Hydrogen Beta filter was created with a select number of low energy nebula in mind such as the Horsehead, Cocoon & the California nebula. In many instances the Hydrogen Beta filter is the **ONLY** way to see these nebula. The Hydrogen Beta Filter is a visual filter only, best suited to 8" or larger aperture telescopes with focal ratios of f/5 or faster.

| | |
|---|---|
| **1.25" Hydrogen Beta Filter** (fits most 1.25" eyepieces) | $99.50 |
| **48mm Hydrogen Beta Filter** (fits 2" eyepieces and Lumicon accessories) | $199.50 |
| **Visual Back Hydrogen Beta Filter** (fits in series on back threads of SCT'S) | $199.50 |

**Special Pricing – Buy two or more Lumicon filters and get a DISCOUNT.**

| | |
|---|---|
| Filters normally priced at $99.50 | pay only $92.50 |
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## TELE VUE PRODUCTS

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|---|---|
| **4X Powermate** for 2" eyepieces | $265 |
| **5X Powermate** boosts magnification 5x | $168 |
| **Ranger 70mm** f6.8 apchromat w/45° diag. | $685 |
| **Pronto 70mm**f6.8 w/45° erecting prism | $925 |
| **Tele Vue 85,**85mm f/7 APO telescope | $1995 |
| **Bino Vue** binocular w/2x correc. | $1030 |
| **Gibraltar** mount with ash wood tripod | $530 |
| **8,11,15mm Plossl** . $82 — **20,25mm** | $95 |
| **32mm Plossl**, widest true field in 1¼" | $110 |
| **55mm Plossl**, widest possible field | $230 |
| **2.0x or 3.0x Tele Vue Barlow** Lens | $105 |
| **2" Giant Barlow** – 2x | $168 |
| **4.8mm Nagler** 82° field, 1¼" eyepiece | $175 |
| **7mm Nagler,** 1¼" eyepiece, 82° field | $220 |
| **9mm Nagler,** 82° field 1¼" or 2" | $240 |
| **12mm Nagler Type 4**, 82° 1¼"or 2" | $340 |
| **16mm Nagler Type II**, 82° 1¼"or 2" | $310 |
| **17mm Nagler Type 4**, 82° 2" only | $370 |
| **22mm Nagler Type 4**, 82° 2" only | $445 |
| **31mm Nagler Type 5**, 82° 2" only | $595 |
| **2" Paracorr** visual coma corrector | $235 |
| **3,4,6,8,10,14mm Radian,**60° field | $228 |
| **15mm Panoptic** 1¼", 68° field | $210 |
| **19mm Panoptic** 1¼", 68° field | $240 |
| **22mm Panoptic** 1¼"/2", 68° field | $280 |
| **27mm Panoptic** 2", 68° field | $330 |
| **35mm Panoptic** 2", 68° field | $365 |
| **NEW! Tele Vue 18mm** radian, 60° field | $228. |

Note: Tele Vue warranty may not be valid outside USA

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| **7x50mm** Pentax PCFV Binocular | $169 |
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| **16x60mm** Pentax PCFV Binocular | $249 |

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| **Superwedge for 10"/12"LX200** ($35p/s) | $395 |

### Other Fine Meade Telescopes at Lumicon

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|---|---|
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| **8"LX10 SCT** w/RA drive/Tripod ($65 p/s) | $995 |
| **ETX 90EC** Maksutov w/std.drives ($20p/s) | $595 |
| **ETX125EC** Maksutov w/std.drives ($30p/s) | $895 |
| **DS80 EC** w/dual drives ($45p/s) | $449 |
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| **12.5"f/4.8** Dobsonian Starfinder ($95 P&S) | $795 |
| **16"f/4.5** Dobsonian Starfinder (frt. COD) | $1195 |
| **16"f/4.5** Equatorial Starfinder (frt. COD) | $2695 |

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing and shipping charge to the price. Slightly lower P&S for payment by check. Lumicon showroom prices are $50 to $100 higher.

*See the Meade ad in this magazine for full descriptions. Starfinders are complete telescope systems with motor drive and finderscope (Equatorial only) and 25mm (48x) eyepiece. New DC motor runs on four AA batteries.*

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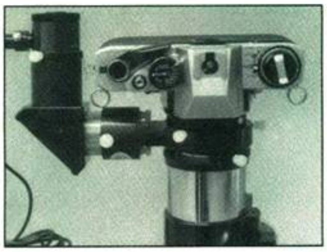

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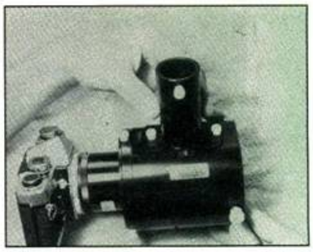

### Lumicon Giant Easy Guider™

The king of off axis guiders is the **LUMICON GIANT EASY GUIDER™.** Made for Schmidtt-Cassegrain telescopes of 10" through 16" diameter, the giant easy guider attaches to the large 3" rear threads of these scopes. Included is an 80mm diameter focal reducing lens capable of delivering f/7 to f/4 photographic speed. Replacing the included 35mm camera adapter (specify camera) with a 2" star diagonal turns the giant easy guider into a full aperture rich-field viewer......................................**$395**

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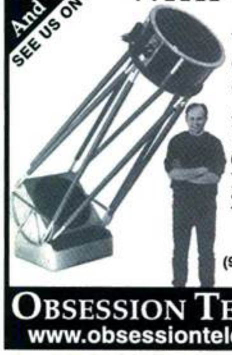

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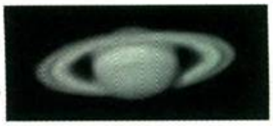

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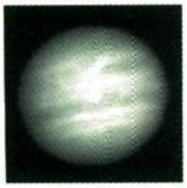

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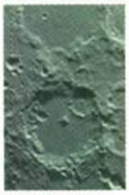

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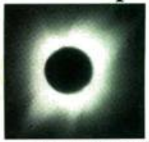

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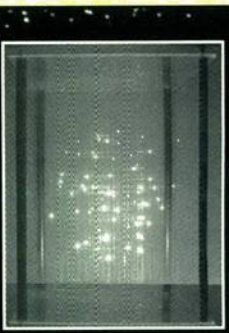

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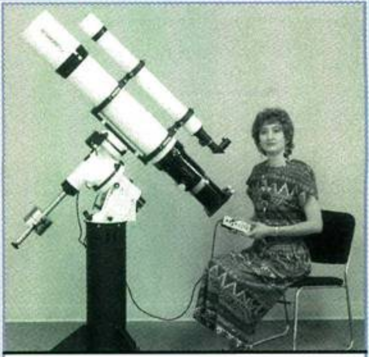

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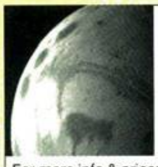

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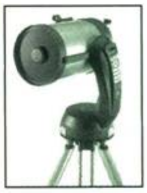

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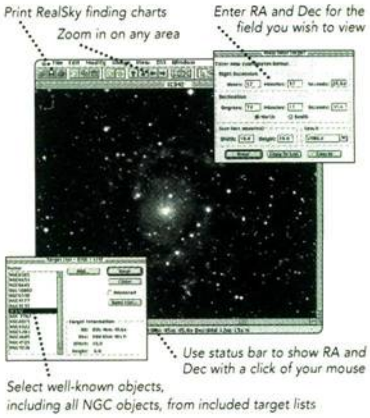
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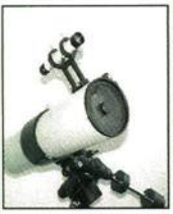

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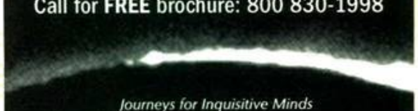

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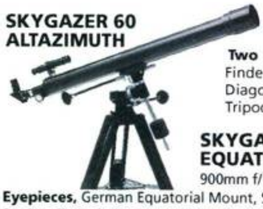

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### Sixteenth Annual Idaho Star Party
Boise Astronomical Society, Bruneau Dunes State Park. Contact: BAS, P.O. Box 8386, Boise, ID 83707; Mike Blackburn, (208) 375-8850; e-mail, bas@micron.net; website, http://www.isidaho.com/bas/.

**AUGUST 4 – 5**
### Société d'astronomie de Montréal
Telescope-making contest near Montréal, Canada. Call Yvan Prégent, (450) 377-2493; e-mail, ypregent@rocler.qc.ca; website, http://www.rocler.qc.ca/caori/cafta/.

**AUGUST 4 – 6**
### Chippewa Valley Astro Society
Northwoods Starfest, Fall Creek, Wisconsin. Contact Hobb's Observatory, Beaver Creek Reserve, S1 County Rd K, Fall Creek, WI 54742; (715) 877-2212; or Bert Moritz, e-mail, mortiz@charter.net.

**AUGUST 4 – 6**
### Nova East Star Party
Smiley's Provincial Park near Windsor, Nova Scotia, Canada. Contact Nova East, c/o John Jarvo, 11 Hickman Dr., Truro, Nova Scotia, B2N 2Z2, Canada; (902) 897-0529; e-mail, novaeast@rasc.ca; website, http://halifax.rasc.ca/ne.

Marty and Marcy Curran

This 40-inch scope was a big draw at the 1999 Weekend Under the Stars in Foxpark, Wyoming.

**AUGUST 12**
### Hurricane Ridge Star Party
Olympic National Park, Port Angeles, Washington. Contact John Gallagher, (360) 417-5191; e-mail, jgalla@orca.esd114.wednet.edu.

**AUGUST 12**
### Shreveport Star Party
Ralph A. Worley Observatory, Shreveport, Louisiana. Contact Cran Lucas, (318) 797-1524; e-mail, clucas@softdisk.com.

**AUGUST 18**
### Dixon Star Party
Sacramento Sidewalk Astronomers and the Davis Astronomy club in Dixon, California. The guest of honor is John Dobson. For information, contact Joseph Roeper, 735 McKenzie Court, Dixon, CA 95620-2215; or e-mail, avidon76@earthlink.net.

**AUGUST 24 – 27**
### STARFEST 2000
North York Astronomical Association. River Place Campground, Mount Forest, Ontario. Starfest hotline: (416) 221-7375. Contact Andreas Gada, 26 Chryessa Ave., Toronto, Ontario, Canada, M6N 4T5; or Tony Ward, e-mail, tonyward@home.com.

**AUGUST 24 – 28**
### Astro Atlantik 2000
New Brunswick Astronomy-Astronomie Nouveau Brunswick, Inc. and Beausejour Astronomy Club. Contact NBANB, 390 Kingsville Road, Saint John, New Brunswick, Canada E2M 4T2; (506) 635-3004; e-mail, bordagea@nbnet.nb.ca; website, http://www.osco.nb.ca/nbanb.

**AUGUST 25**
### Hudson Valley Star Party
Mid-Hudson Astronomy Association. Call (914) 485-5669; or (914) 758-6305; e-mail, mhaa@geocities.com; website, http://jump.to/mhaa.

**AUGUST 25 – 26**
### Star Gazing with Hansen Planetarium
Morefield Campground, Mesa Verde National Park, Colorado. Contact Dale McFarland, (800) 449-2288.

**AUGUST 25 – 27**

### Conjunction: An Event for Amateurs

Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact Jack Megas, 311 Surrey Road, Springfield, MA 01118; e-mail, Rsanderson@Juno.com.

**AUGUST 25 – 27**

### Saskatchewan Summer Star Party

Cypress Hills Interprovincial Park. Contact SSSP – 98, RASC Saskatoon Centre, P.O. Box 317, RPO University Saskatoon, S7N 4J8, SK, Canada; e-mail, dickson@sk.sympatico.ca; or Erich Keser, (306) 374-4262; e-mail, solose@skyway.usask.ca.

**AUGUST 25 – 27**

### Western Colorado Regional Star Party

Grand Junction, Colorado. Call Steve Renner, (970) 242-3765; e-mail, mdonn28253@aol.com.

**AUGUST 25 – 27**

### RocheSTARFest

Wolk Observatory, Ionia, New York. Contact Lori Englund, P.O. Box 20292, Rochester, NY 14602; e-mail, lenglund@frontiernet.net; website, http://www.ggw.org/asras.

**AUGUST 26 – 27**

### Lake Whitney Summer Star Party

Workshop on mirrors and telescopes. Lake Whitney, Texas. Contact Thomas Williamson, (817) 656-0901; e-mail, distglow@hotmail.com.

**AUGUST 30 – SEPTEMBER 4**

### Alberta Star Party

Caroline, Alberta. Contact Rick or Carol Weis, 4612 – 17th Avenue N.W., Calgary, Alberta, T3B 0P3; (403) 286-4347; e-mail, weisc@cadvi sion.com.

**AUGUST 31 – SEPTEMBER 3**

### Oregon Star Party 2000

Ochoco National Forest. Contact Lars D. H. Hedbor, (503) 722-3849; e-mail, osp_publicity@hotmail.com.

### CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187, or to cryback@astronomy.com. Look for additional events at http://www.astronomy.com.

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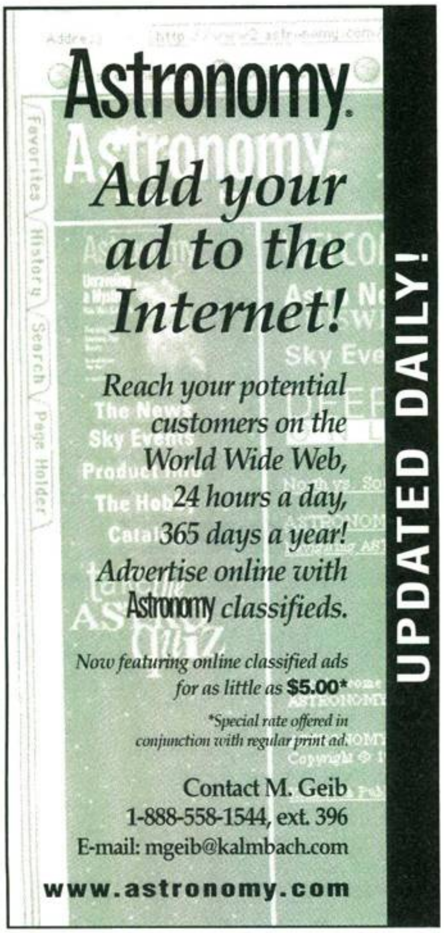
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*AURORAE*

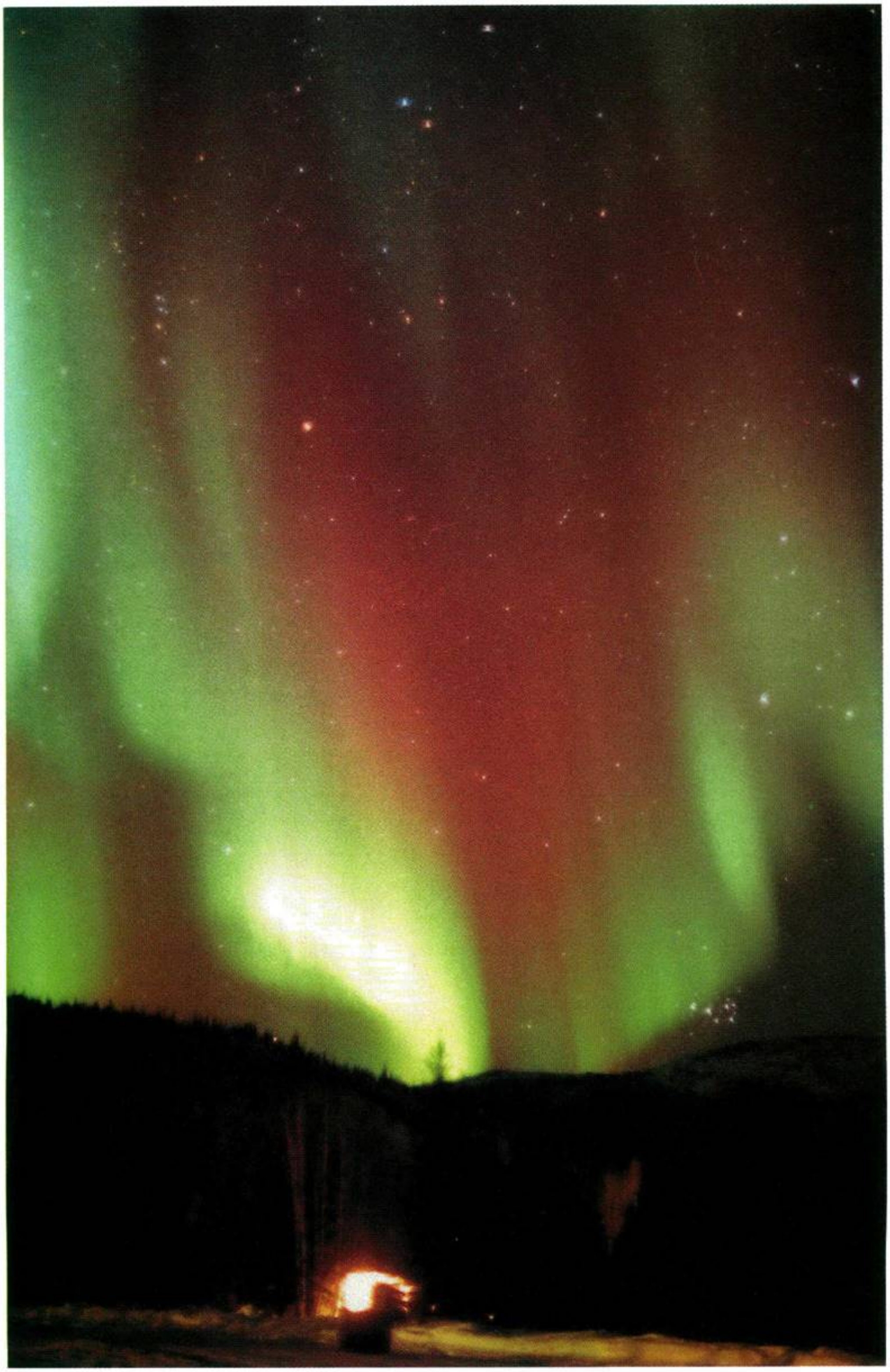
# Sharing the Northern Lights

### A father and daughter enjoy solar maximum's splashy aurorae.

▶ On the evening of February 11, I gave a snowmobile ride to my four-year-old son Ty and my nine-year-old daughter Paige. It was getting cold so we kept it short. Our routine is to drive to the top of the hill in the middle of the field where we remove our helmets and gaze at the stars. I try to point out planets or other celestial bodies and give them some background to help them appreciate the night sky.

On this night there was a faint, rosy glow on the northern horizon. I told my daughter that the last time I had seen a reddish aurora anywhere near that bright was 9 years ago when she was an infant. My son, of course, claimed to have seen it too, but for some reason we didn't believe him. I told them that if these lights "turned on" it could be spectacular. The temperature had dropped to zero and it was late so we came back to the house and turned in for the evening. One of the last things my daughter asked was to be awakened if the northern lights "turned on" like I hoped they would. I promised her I would.

My attempts at sleep were interrupted every few minutes by an impulse to run to the windows to check the lights and fulfill



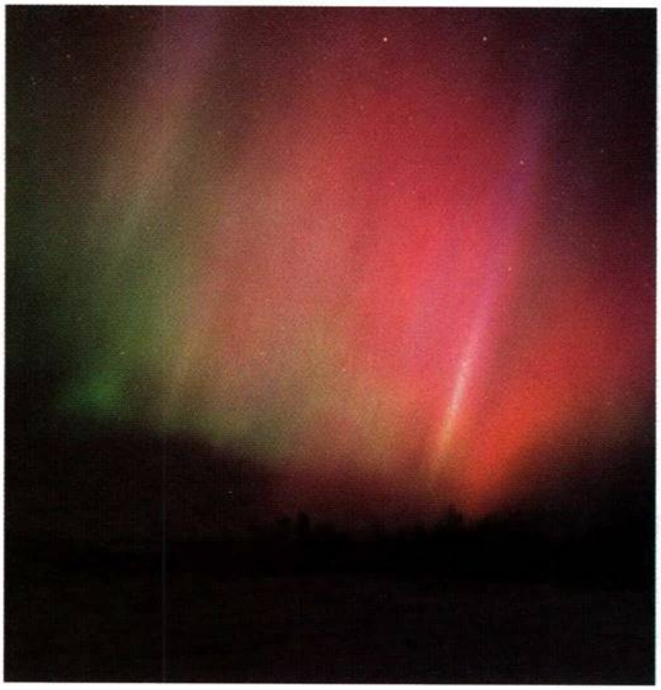
**Aurora on the *Astronomy* Tour**

**DAVID M. BUCHLA**

(50mm lens at f/1.4, Kodak GT 800 film, 8-second exposure taken March 5, 2000, from Chena Hot Springs, Alaska) my promise to my daughter. At around 1:30 A.M. my wife kicked me out of bed, so I went to lie on the couch and keep my vigil without disturbing her. The windows were beginning to frost and the temperature had fallen to around –10° F. The auroral sheets continued surging but without any red hues. The phosphorescent greens weren't what I had hoped for, but they were exceptionally bright, so I woke my daughter up.

We stepped onto the porch, and I warned her that when the outside door opened she was going to get a blast of frigid air. I said she should scan the horizon quickly. When the door opened her eyes grew big and she said, "Wow! That's pretty!" I caught a glimpse of red out of the east, asked her to step back, and poked my head out the door . . . on the northeastern horizon there were beacons of red with broken shards of magenta light shooting upward. I swept my daughter off her feet and stepped out onto the porch with her. We were both in awe. We enjoyed the show for as long as my bare feet could stand it. When tucking her back into bed she said, "Thank you, Daddy."

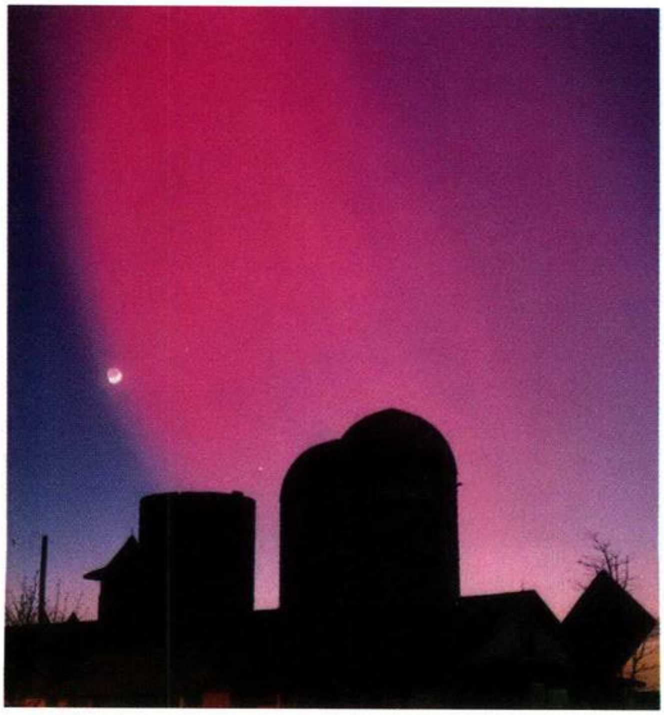
Now I had work to do. I threw on my snowmobile suit and hit the field with my camera. The first five or six exposures worked fine but the film became like leather and the batteries weakened. I returned to the house, took the camera apart to remove the battery pack and warmed it up on the coffee maker. I then returned to the garage and put everything back together for more exposures. The northern lights would simmer to a glow and then erupt into



**Lighting Up the North**

DUANE CLAUSEN

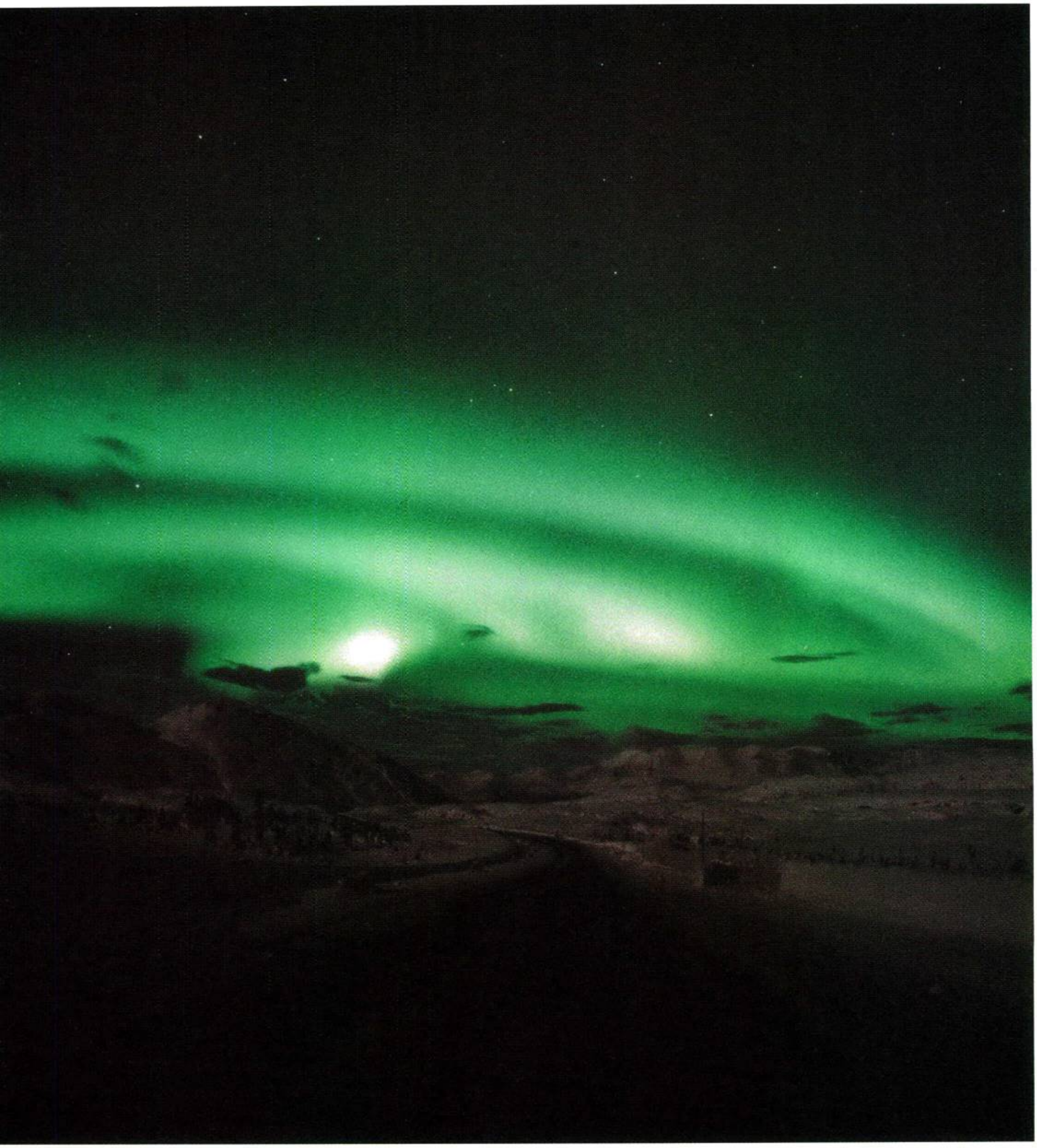
(28mm lens at f/2.8, Kodak Gold 200 film, 25-second exposure taken February 12, 2000, in the Upper Peninsula of Michigan)



**Pink Skies in Pennsylvania**

HARRY ORLIND

(35mm lens at f/3.5, ISO 400 film, 12-second exposure taken April 6, 2000, from Montgomery County, Pennsylvania)



**Swirling Bands over the Klondike Highway**

**MICHAEL KLENSCH**

(24mm lens at f/2.8, Fuji Superia 200 film, 20-second exposure taken February 8, 2000, from the Canada/Alaska border) fiery colors. Running back and forth to the house about half a dozen times to warm the batteries helped, but now the camera's shutter would not open either on the timer or manually.

As morning approached, the color show was actually peaking. But my camera was not working — the timer would beep faster and faster and then . . . nothing. I needed power, just a little. What would NASA do? Divert power, shut down unnecessary functions. But how do I do that? The timer! It beeps; beeping takes energy. I turned the audio portion of the timer off and recomposed my shot. Will it work? I depressed the timer button and stood back. The reflected red from my camera pulsed progressively faster on the snow, and I imagined the beeping that normally accompanied the strobe. Then the moment of truth. Cashunk! The shutter opened! I recomposed, and it opened again and again. . . .

When my daughter was about 4 years old we used to sleep out under the stars in our sleeping bags, watching meteor showers and pointing out constellations and planets. In 1997 my two-year-old son had to say goodnight to Comet Hale-Bopp every night. These were defining moments that drew us together. I hope that my children will remember them and share similar experiences with their own children. I'm sure there will be more, but I owe the shots I made of the northern lights to inspiration from NASA, my coffee maker, and a nine-year-old girl. ◾

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*Duane Clausen lives in Menominee, Michigan.*

**Clusters and a Conjunction (left)**

RANDALL WEHLER

(50mm lens at f/2, Elitechrome 100 film, 1-second exposure taken April 7, 2000)

**NGC 2359 in Canis Major (above)**

KEN BLANKENSHIP

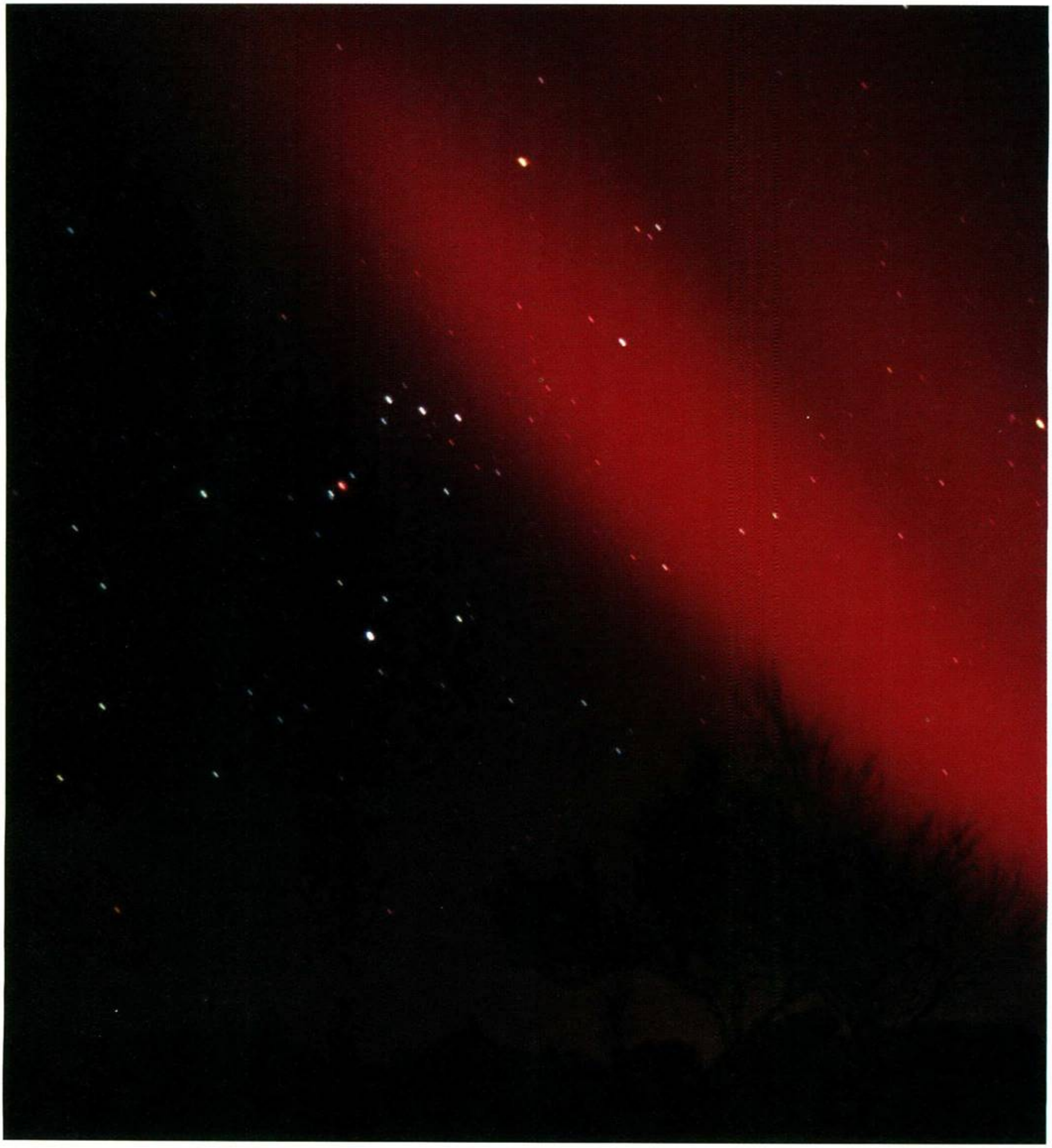
(14-inch SCT at f/7.5, hypered Kodak PJ 400 film, composite of two 4-hour exposures)

**Moonrise over San Diego (below)**

JERRY SCHAD

(200mm lens, Fuji Velvia ISO 100 film)

*This month's best astrophoto*



### A Descending Red Curtain

**CHUCK ADAMS**

(28mm lens at f/2, Kodak Elite 100 film, 40-second exposure taken April 6, 2000, from Blue Ridge Parkway, North Carolina)

On April 6, 2000, an active aurora greeted observers out to see a planetary conjunction. The aurora was seen as far south as Florida.

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